New Scientist

SPECIAL ISSUE

WEEKLY 4 February 2023

WHAT COVID DOES TO THE BRAIN

MONGOOSE WARFARE

THE PLANET THAT SHOULDN'T EXIST

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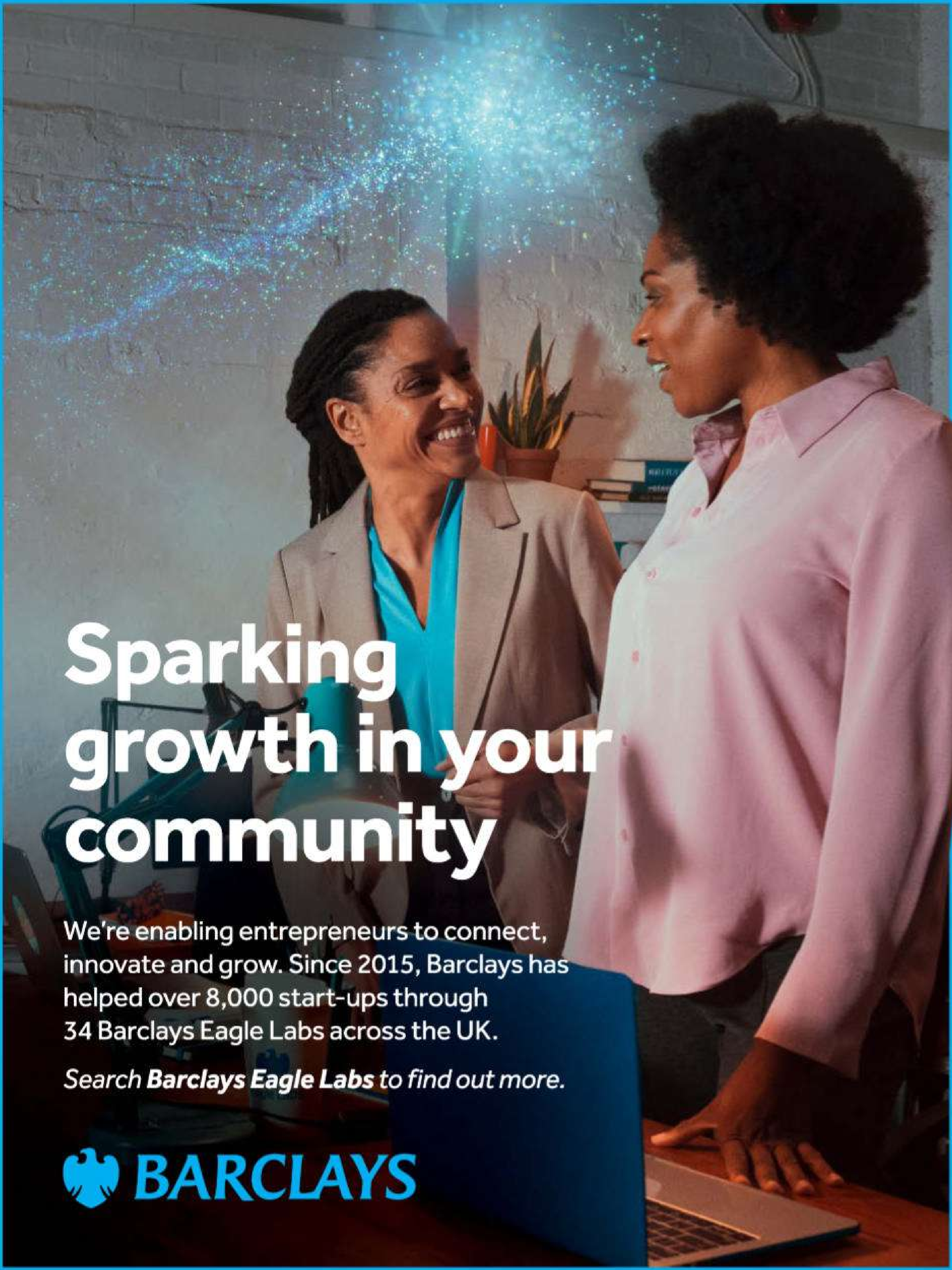

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Virtual event

Secrets of the Large Hadron Collider

Join particle physicist Clara Nellist, part of the ATLAS experiment at the LHC, for a deep dive into the past, present and future of the largest particle collider ever built. Find out how the LHC expands our knowledge of the universe and learn what it is like to work on one of the world's greatest physics experiments. Catch it on 7 February at 6pm GMT/1pm EST. Tickets cost £14.

newscientist.com/events

Tour

Chile: The world capital of astronomy

With unique geographical and climate conditions – and 70 per cent of the world's large telescopes – Chile is the global capital of astronomy. Join *New Scientist* features editor and astronomer Abigail Beall to explore the Atacama desert and visit world-leading observatories. The 12-day tour begins on 27 March and costs £7999.

newscientist.com/tours

Podcast

Weekly

How impactful will new vaccines against the respiratory virus RSV be? The podcast team examines the evidence and also gets to the bottom of a story about Earth's core. Plus, in a bonus episode, podcast host Rowan Hooper and environment reporter Madeleine Cuff talk to climate scientist Tim Lenton, co-author of a recent report on the climate benefits of vegan burgers.

newscientist.com/nspod

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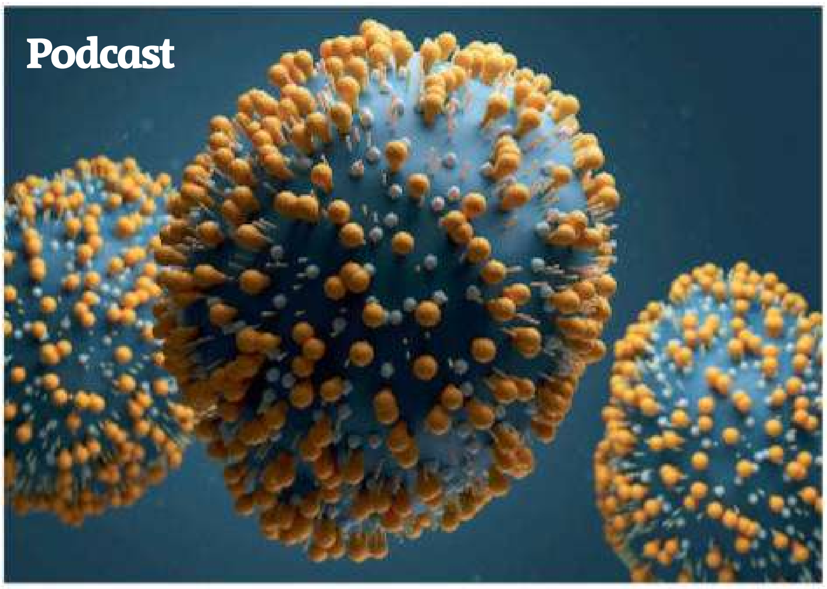
Do look up Visit Chile for unrivalled views of the night sky



JOSHIMER BIÑAS/ALAMY

Vaccine boost New treatments for RSV may be approved soon

Video

Robots on the beach

On our YouTube channel this week there is a video of Raibo, a quadrupedal robot that can run effortlessly at speeds of up to 10 kilometres per hour across soft sand. The robot has been equipped with new software that allows it to learn how to navigate changeable terrain – which means Raibo can now even run across squishy materials like air mattresses.

youtube.com/newscientist

Newsletter

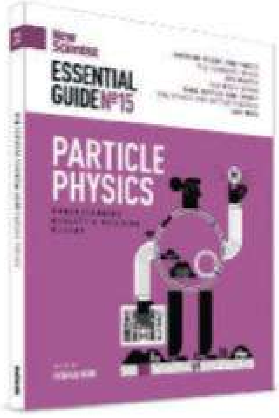
Launchpad

The James Webb Space Telescope has just examined Chamaeleon I, a dust cloud where stars are beginning to form. And, says our space reporter Leah Crane, it has found that the dust contains complex organic molecules. This means planets that form from the dust may be life-friendly.

newscientist.com/launchpad

Newsletter

"Planets might be born with some of the building blocks of life already baked in"



Essential guide

The past century saw a revolution in our understanding of the building blocks of reality and led to the "standard model" of particle physics. Learn about the model in this *New Scientist Essential Guide*. Available to download in the *New Scientist* app or to purchase in print from our shop.

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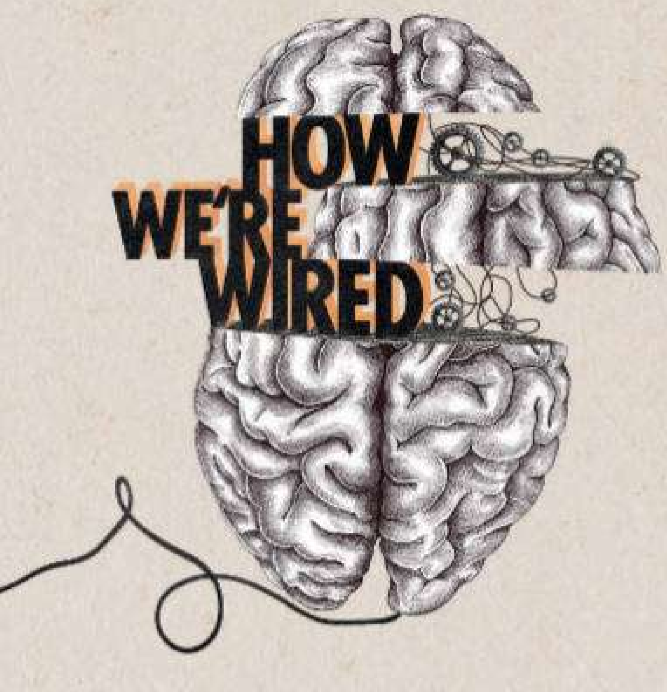
OWN YOUR MIND BUSINESS

Discover what makes you tick with How We're Wired, a brand new podcast that looks at what happens inside your brain – from before you were born through to death.

Presented by anthropologist Dr Anna Machin, this series features real life stories, expert analysis, the latest research and at-home experiments that will open your eyes to the most fascinating organ in the human body.



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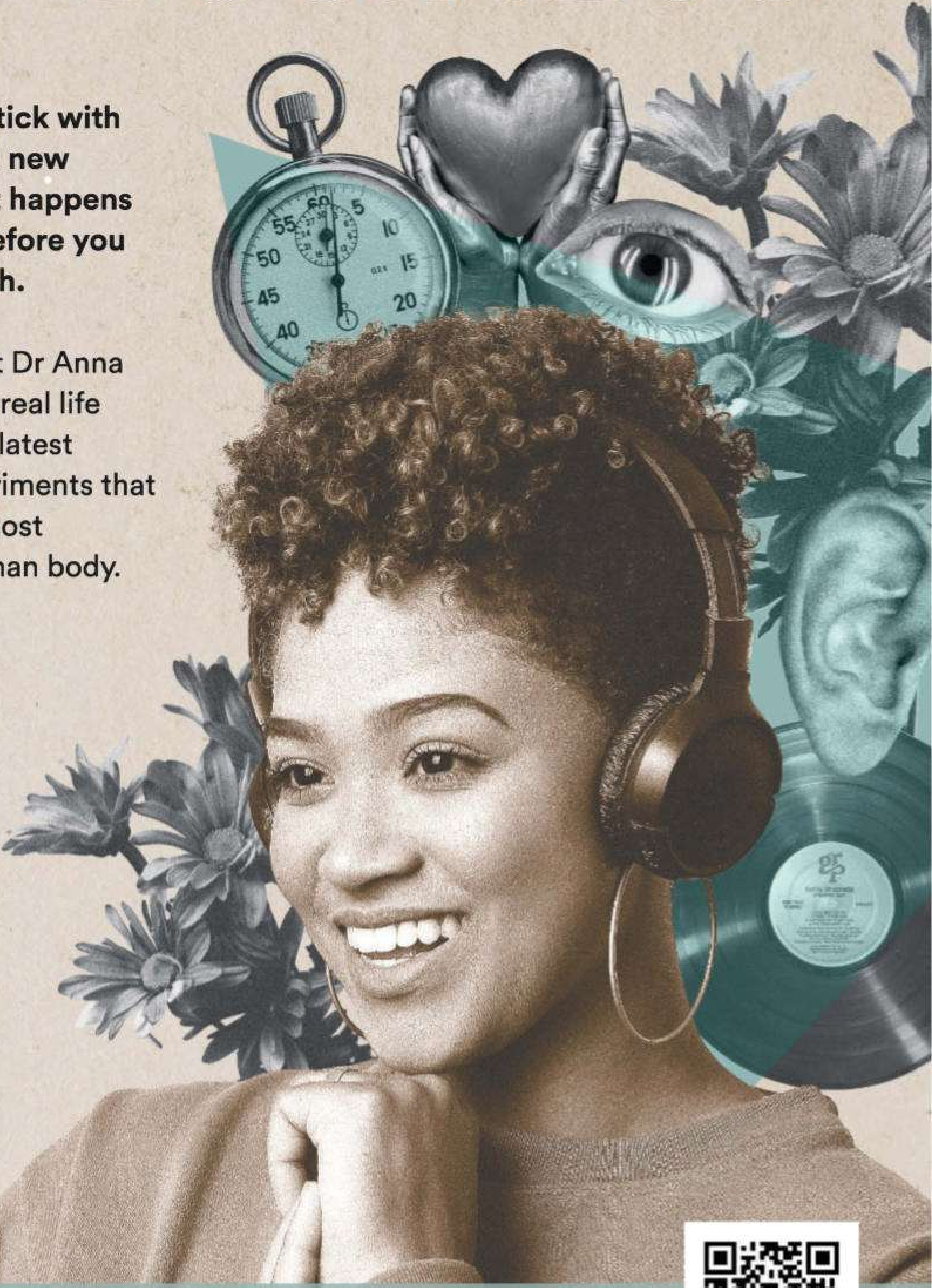

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Boost from within

When preparing for pandemics, let's not forget our own immune systems

A FEW months into the covid-19 pandemic, it was rare to have a conversation without antibodies, vaccines and viruses being mentioned in the same breath. More than three years on, we shouldn't let that interest wane – especially as we face one of the coronavirus's latest variants, XBB.1.5, or "Kraken" as some have named it.

It certainly appears to be deserving of its monster moniker. This subvariant of omicron is now the dominant strain in the US and is spreading rapidly throughout Europe and Asia.

It is the most transmissible subvariant discovered yet, due to changes in its spike protein, the part of the virus targeted by vaccines. The World Health Organization has warned that it may also have the best ability to evade our immune defences to date, although vaccines will still remain effective against severe disease.

This is an important reminder that we must continue to focus on pandemic preparedness, disease monitoring and the pursuit of knowledge about our own immune system. In doing so, we will be in the best position to face the inevitable curveballs that this coronavirus – and other pathogens – continue to throw us.

"We must continue to invest in the pursuit of knowledge about our immune systems"

To help with this endeavour, we have answered eight of the biggest questions in immunology in our special issue beginning on page 36. There you can start by discovering how strong your immune system is – or isn't. If it is failing to live up to its full potential, perhaps a change of diet could help (see page 41).

We also take a look at the cutting-edge immunotherapies that are working against cancer (page 39) and discover the secrets of those annoying people who never seem to get sick (page 40). Plus, there is surprisingly good news about how lockdowns affected our children's health (page 38) – and the special contains much more besides.

As we work on ways to stop Kraken and its ilk from spreading outside our bodies, we can also bolster our own immune systems to help them fight for us from within. ▮

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CLEMENS FISCHER

Astronomy

Visitor from the outer reaches

A green comet usually found on the outskirts of the solar system has made its closest pass by Earth since the Stone Age, reports **Leah Crane**

A RARE green comet hailing from the outermost edges of the solar system passed by Earth this week, and is now heading back into the black.

This lump of ice usually dwells in the Oort cloud, a belt of icy objects that orbit up to 100,000 times as far from the sun as Earth. But on 1 February, it came within about 45 million kilometres of our planet – about 120 times the distance between Earth and the moon.

The comet, called C/2022 E3, takes about 50,000 years to complete its orbit around the sun, so its last pass by Earth was in the Stone Age, when our ancestors still coexisted with Neanderthals.

Those early humans may have been able to see C/2022 E3 in the sky, and it was possible to spot with the naked eye on this pass, too. Reports of sightings have come in from areas across the northern hemisphere, mostly from regions with little light pollution to obscure the fuzzy-looking comet. Sadly, it isn't visible in the southern hemisphere.

It can be seen near the constellation Boötes, just to the east of the Little Dipper, and it should remain visible until the middle of February using a telescope, binoculars or a camera with the option for an extended exposure. After that, it will slip away, back towards the Oort cloud.

C/2022 E3 was first spotted by astronomers using the Zwicky Transient Facility in California in March 2022, when it passed within the orbit of Jupiter. Its coma – the cloud of gas surrounding the main body, or nucleus, of the comet – appears green because of sunlight hitting carbon gas. It isn't just any carbon, though – it is a relatively rare type called diatomic carbon, which consists of two carbon atoms bound together.

Once the strange comet leaves Earth's neighbourhood, some observations have hinted that it might be travelling fast enough to leave the solar system altogether. Others suggest it may have its orbit bumped around by the gravity of the planets, so that it won't pass by again for millions of years. ▮

The green glow of comet C/2022 E3 as seen on 29 January from the UK

Biology

Parental care may shape evolution

Animals that care for their young accumulate more genetic mutations in the population, which could have positive and negative consequences, reports **Michael Le Page**

AN EVOLUTION experiment involving beetles has provided the first direct evidence that caring for offspring results in the accumulation of more genetic mutations in a population, affecting how animals evolve.

Some of the mutations are likely to be harmful, but there is also a positive side, as having more variation may allow populations to adapt and evolve more quickly when circumstances change. "You're holding in a lot of deleterious stuff," says Rahia Mashoodh at the University of Cambridge. "But also, you're holding in potentially a lot of good stuff that is going to help you rapidly adapt."

Mutations constantly occur in cells, meaning that all animals have mutations their parents didn't. Every human has around 50 to 100 new mutations, for instance. Many of these make no difference, a few might be beneficial and some are harmful.

There are also evolutionary processes that remove mutations from animal populations. Individuals that inherit lots of harmful mutations are more likely to die without reproducing.

The average number of mutations in individuals in any population – called the mutation load – depends on the strength of these evolutionary processes, and will change when their strength changes. It has been suggested, for instance, that the decrease in child mortality around the world over the past centuries is leading to an increase in the mutation load.

In theory, parental care in any animal should lead to the accumulation of mutations in the population by enhancing the survival of offspring, but this has never been put to the test. To do so, Mashoodh and her colleagues have been experimenting with burying beetles (*Nicrophorus vespilloides*), also known as sexton or carrion beetles.

BLICKWINKEL/H. BELLMANN/F. HECKER/ALAMY

Burying beetles sometimes look after their offspring

These beetles seek out the dead bodies of small animals, such as mice or birds. A male and female will pair up at a corpse, fight off other beetles and bury the body. They will then remove any feathers or fur on the corpse before coating it in antimicrobial fluids to form a so-called carrion nest. They also remove the gut and smear it over the nest. Then they lay eggs nearby.

Unusually among beetles, the parents may stick around and care for the young. They not only protect them from predators, but also feed the larvae regurgitated carrion. The larvae even beg for food by raising up the front half of their bodies.

The level of parental care varies in the wild, Mashoodh says, with the adults sometimes leaving after laying eggs. So she and her colleagues set up four populations of 60 to 80 beetles in the lab. In two, the parents were removed after laying eggs. In the other two, the parents remained with their offspring throughout their time as larvae.

The populations were allowed to evolve over 30 generations, and the entire genomes of a few larvae were sequenced within each generation.

The "no care" populations rapidly evolved to cope with the loss of parental care. For instance, their mandibles became larger to help them penetrate the carrion nest, and they also became more social and cooperative with their siblings (bioRxiv, doi.org/jt85).

"Adult burying beetles protect the larvae from predators, and also feed them regurgitated carrion"

"They have to rely on their sibling instead of their parents," says Mashoodh. "They're able to rapidly adapt because they harbour so much genetic variation."

At the end of the experiment, there was less genetic variation among the no-care populations than among the cared-for populations, as measured by the number of single-DNA-letter mutations. "If we remove care, a lot of genetic variation is whittled away," says Mashoodh.

Harmful effects

The researchers also showed that many of these mutations are harmful. When they inbred beetles – resulting in offspring having the same mutations in both copies of genes, not just one copy – the populations that received parental care went extinct faster than the ones without parental care.

The findings may apply to any kind of cooperative social interactions in animals, says Mashoodh. "I do think this is a more general principle."

"It is very interesting work," says Ruben Arslan at the University of Leipzig in Germany, whose work suggests unexpected processes are limiting the mutation load in people despite the fall in child mortality. "This has been much-discussed and posited but without much experimental evidence to show for it."

Katrina McGuigan at the University of Queensland in Brisbane, Australia, has some concerns about the study's methods. "At a brief glance, I'm somewhat sceptical of the interpretation that the parental care treatments did differently affect the genetic variance," she says, saying the differences could be due to chance or environmental conditions.

But Mashoodh says the team has taken the methodological issues raised by McGuigan into account in its calculations. ▮

Artificial intelligence

DeepMind AI is as fast as humans at solving previously unseen tasks

Alex Wilkins

DEEPMIND has developed an artificial intelligence that can solve tasks it has never seen before as quickly and as accurately as humans – a possible step towards generally intelligent AI.

The AI, called Adaptive Agent or AdA, works in a 3D virtual world where it is asked to solve tasks that involve navigating, planning and manipulating objects.

Humans are excellent at solving new problems, including in environments they haven't seen before. For instance, once you have learned to drive a car, it is relatively straightforward to drive one in another country.

AI systems, however, tend to be able to solve only the problems they are trained to master and struggle if the rules change.

Much of DeepMind's success with game-playing AIs, such as its chess-playing AlphaZero, has come from reinforcement learning, where an AI is taught what success looks like and is left to figure out the rules, and how to succeed, using trial and error.

The AI would have to be trained all over again to be able to play a different game, though.

To get around this limitation, DeepMind has been developing an AI that can succeed at games it hasn't seen before. In 2021, it released details of an AI model that could solve new tasks in a virtual 3D world that contained more than 700,000 games, including hide and seek, capture the flag and abstract, automatically generated games.

> "This work is quite a step forward – an agent that can quickly learn how to solve new problems"

The team has now developed this AI by training various versions of it on a set of billions of tasks – allowing between one and six tries on each task, whether they succeed or not – for the equivalent of 100 years.

The virtual world AdA lives in has 10^{42} tasks, more than the number of observable stars in the universe, and rules, similar to laws of physics, that can be changed.

When the DeepMind team tested the AI on 30 custom test tasks it hadn't been trained on, it performed as well as and as quickly as 100 human participants in solving them, and could solve some that the people couldn't.

It could solve about 90 per cent of a larger, automated set of 1000 previously unseen tasks (arxiv.org/abs/2301.07608).

The model also seemed to display unexpected skills. On tasks that required multiple in-game agents to solve them, the system could control several agents, displaying coordination and cooperation, kinds of intelligence that are hard to produce in AIs.

DeepMind wouldn't comment on the work, but Özgür Şimşek at the University of Bath, UK, says: "This work is quite a step forward, showcasing an agent that can develop, in some sense, a deep understanding of its environment and quickly learn how to solve new problems in this environment."

AIs that can tackle problems in this way could be useful for tasks from humanoid robots doing manual labour to self-driving cars learning new environments.

DeepMind's AI solving unseen problems in a similar amount of time to humans is impressive, says Şimşek, but it doesn't mean it can handle life outside its virtual environment. "It's a closed world, lacking the types of uncertainty that we generally have to deal with in the real world." ▮

Animal behaviour

Fishing partnership benefits dolphins and humans

DOLPHINS that collaborate with humans to catch fish in Laguna, southern Brazil, have a higher rate of survival than those that don't work with people.

While dolphins that practise the technique seem to catch more fish, some of the survival benefit is because the dolphins avoid being caught in trammel nets used for fishing in other areas by the coast, says Mauricio Cantor at Oregon State University, whose team has been studying the behaviour with underwater cameras and microphones for 12 years.

Between May and August, bottlenose dolphins (*Tursiops truncatus*) drive migrating schools of mullet (*Mugil liza*) towards the coast, where fishers are waiting. When the dolphins do a final deep dive to drive the fish closer to shore, fishers drop their nets – but they have to act at exactly the right time or lose their chance.

The fishers watch for the dolphins arching their backs, which reveals they are about to dive deeply. Less often, the animals seem to signal to the humans by slapping the water with their heads or tails. If the fishers drop their nets on the dolphins' cues, they are 17 times more likely to catch mullet than if they do so at other times, Cantor's team found.

It is harder to work out how much more successful at catching fish the partnership makes the dolphins, says Cantor. But the locals report that the dolphins often dive into their nets to remove some fish. The nets could also aid the dolphins by forming a barrier that stops the mullet fleeing, he says.

DR. BIANCA ROMEU/UFSC

A bottlenose dolphin and a fisher working together in Laguna, Brazil

About 10 dolphins work with humans out of a group of 60 or so. The team calculated that dolphins that cooperated with people were 13 per cent more likely to survive through the study period than ones that didn't (*PNAS*, doi.org/jvbf).

The other dolphins may have to catch fish without human help because there are only a few places near this coast where the technique is possible, says Cantor.

Bruno Díaz López at the Bottlenose Dolphin Research Institute in Galicia, Spain, says dolphins are one of the few animals that have unique cultures, where behaviours are shown by only certain groups and are shared between individuals. "They need to teach each other this," he says. ▮

Clare Wilson

Astronomy

Supernovae might be a good cue to hunt for alien signals

Jonathan O'Callaghan

NASA GODDARD

Supernova SN 1987A sits below the centre of this image, in its luminous ring

IF WE want to spot messages from aliens, letting supernovae guide our search could help. Intelligent aliens might choose to transmit evidence of their presence amid such attention-grabbing cosmic events because it would mean their signals would be more likely to be seen, according to researchers at the Berkeley SETI Research Center in California.

Roughly once every 100 years, a star explodes as a supernova in the Milky Way. These flare-ups shine brightly and are visible across the galaxy as the light from the event spreads out. They would even be visible to observers in other galaxies.

The most recent supernova in the Milky Way visible on Earth was SN 1987A, seen for the first time on 23 February 1987, which lasted for several months.

Bárbara Cabrales at Berkeley SETI and her team propose that, for example, looking at exoplanets that had also seen the light of this supernova might be a good idea if we want to find signs of advanced alien life.

"We can get smart about where we're looking," says Cabrales. "We know which [star systems] have seen this big, bright event. So which one of those has had enough time to see this event and [also time to] send a signal to us?"

In work presented at a meeting of the American Astronomical Society in Seattle last month, Cabrales identified 32 stars using NASA's Transiting Exoplanet Survey Satellite whose planets meet those criteria and could be good targets for further study. All were close enough that anything living on worlds there may have been able to see supernova SN 1987A and had time for a signal to reach us.

100

Years between supernova explosions in the Milky Way

32

Number of star systems that witnessed a supernova in 1987

There will be other star systems in years to come that will eventually also see the light from this supernova as it travels further, making them good future targets, say the researchers.

Jason Wright at Pennsylvania State University says the idea could be a good way to rank stars that we should target to hunt for intelligent life. "There's an enormous amount of stuff to look through," he says. "This adds to the list of ways in which we can prioritise stars."

It might also make sense for us to transmit our presence more broadly the next time we see a supernova, if we want anything that is employing the same search method on another planet to spot us. "If a supernova were to go off right now, I say we send a signal," says Cabrales. "Maybe someone will see it." ▮

Animal behaviour

'Love hormone' not crucial for social bonding after all

Sam Jones

PRAIRIE voles lacking receptors for oxytocin still bond with mates and their young – contradicting ideas about the role of this "love hormone" in such behaviours.

Oxytocin is released in the brain during social bonding, romantic intimacy and parenting, as well as during labour and lactation. Scientists have long studied its role in mammals, including prairie voles (*Microtus ochrogaster*), which show attachment to one long-term partner, known as pair bonding.

For decades, drug studies suggested oxytocin receptors were essential to produce bonding. But when Devanand Manoli at the University of California, San Francisco, and his team removed these receptors in prairie voles using CRISPR gene editing, they found that the animals still pair bond.

Prairie voles lacking the receptors gave birth and nursed their young, spending long periods of time grooming and huddling with them. However, vole pups born to mothers lacking oxytocin receptors weighed significantly less when they reached weaning age, suggesting that the mother had issues with milk production or nursing. They were also less likely to survive to weaning age (*Neuron*, doi.org/grpwnv). "It's not surprising that there isn't a single point of failure for behaviours as important to a species as attachment," says Manoli. ▮

Prairie voles bond with one partner, even without oxytocin receptors

PICASA

Biology

Complex life began with teamwork

Brief alliances between simple organisms may have driven the evolution of multicellular ones

Claire Ainsworth

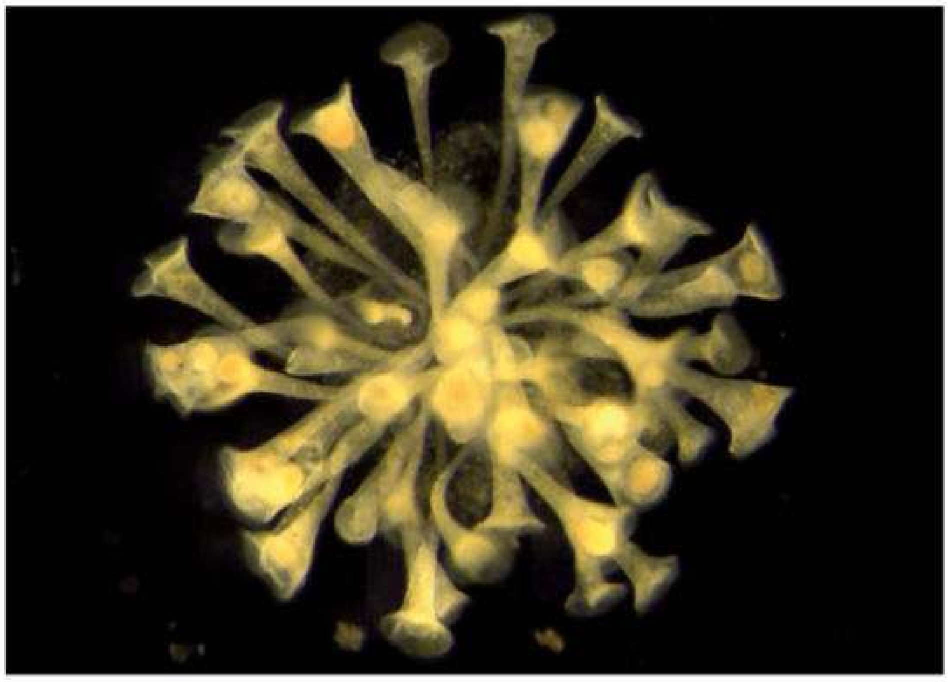
A GIANT, trumpet-shaped cell that skulks in the bottom of ponds has given scientists a new clue about how single-celled creatures may have taken the first steps towards evolving into multicellular ones, a key transition in the evolution of life.

For this to happen, there had to be a benefit for single cells to club together, such as improved reproduction or feeding. Studies investigating these ideas have focused mainly on creatures that form groups or colonies in which some cells develop specialised functions, and where they remain glued together for some or all of the time. Biologists think they may represent a stage of evolution that is partway down the path to multicellularity.

Shashank Shekhar at Emory University in Atlanta, Georgia, and his colleagues have spotted a simpler, reversible form of multicellular behaviour in *Stentor coeruleus*, a single-celled protist that can sometimes reach 2 millimetres in length.

Shekhar was studying *Stentor* in a lab dish when he noticed that individual cells use a fringe of whip-like cilia around their "heads" to generate pairs of vortices to suck food into their "mouths". Furthermore, while some cells were freely swimming around, other cells stuck to the dish and formed colonies. He wondered whether this helped *Stentor* trap more food.

***Stentor coeruleus* cells forming a colony with their "mouths" sticking out**



SHEKHAR ET AL.

To find out more, Shekhar and his team put pairs of *Stentor* cells in a fluid-filled chamber. The cells put their heads together and their vortices combined, creating a much stronger flow that could draw in more and bigger prey (bioRxiv, doi.org/jt7x). "It almost appears like a single, big *Stentor* instead of two small *Stentor*," says Shekhar.

If this is so advantageous, why don't *Stentor* cells stick together all the time? Shekhar thinks it is because the benefit is unequal, with the stronger cell getting a better deal than the weaker one. So the cells in colonies waggle their heads between each neighbour, swapping partners all the time to maximise their fluid flow.

"By giving up a little bit of their independence, they are benefiting as a whole, as a colony," says Shekhar. While the colonies remain roughly constant in size, each *Stentor* comes and goes, like a guest at an open house party.

The findings describe a form of simple multicellularity that is driven by a fast and reversible cellular behaviour, rather than a programmed and irreversible developmental process, says Thibaut Brunet at the Pasteur Institute in Paris. "This provides an unusual and elegant possible route for the early evolution of multicellularity that had not been quite on the radar before." ▮

Animals

Bigfoot sightings rise where black bears are abundant

AMERICAN black bears are being mistaken for Bigfoot throughout North America. For every 900 bears in an area, one Bigfoot sighting is likely to follow, according to an analysis of bear populations and sightings of the mythical being.

The legend of Bigfoot – a bipedal, hairy, ape-like creature – first cropped up during the late 1800s and gained a particularly strong foothold among people who live in or near the forests of the western US. The mystery has since been fuelled by grainy photos, disputed footprints and anecdotal encounters, though there is no hard evidence that Bigfoot exists.

That led Floe Foxon at data analysis firm Pinney Associates in Maryland to investigate if another animal could be responsible for a significant portion of Bigfoot sightings. Though black bears usually travel on all four legs, they can stand and walk on their hind legs, making them a prime suspect.

Using a statistical model, Foxon compared the number of American black bears (*Ursus americanus*) in US states and Canadian provinces with the number of reported Bigfoot sightings in those regions. Foxon accounted for the human population and available bear habitat in each area. The model revealed a strong correlation between bear populations and the number of Bigfoot sightings compiled by the Bigfoot Field Researchers Organization (bioRxiv, doi.org/jt8b).

It is feasible that "a flash of fur and an upright standing figure" could be mistaken for Bigfoot, says Jeffrey Meldrum at Idaho State University, though he says the research is "extremely preliminary". Meldrum, who wrote a book on the mythical being, adds that the reverse could be true: that genuine Bigfoot sightings may be dismissed as black bears.

"A flash of fur and an upright standing figure could be mistaken for Bigfoot"

The number of Bigfoot sightings in an area could help researchers keep tabs on black bear populations, which have been generally increasing since the 1990s, though Foxon warns there is always the risk of hoax Bigfoot reports inflating bear numbers. ▮

Corryn Wetzel

Robotics

Tiny metal robot can melt its way out of tight spaces to escape

Karmela Padavic-Callaghan

A MINIATURE, shape-shifting robot can liquefy itself and reform, allowing it to complete tasks in hard-to-access places and even escape cages. It could eventually be used as a hands-free soldering machine or a tool for extracting swallowed toxic items.

Carmel Majidi at Carnegie Mellon University in Pennsylvania and his colleagues created a millimetre-sized robot that can not only shape-shift, but also become stronger or weaker by alternating between being a liquid and a solid. It is made from a mix of the liquid metal gallium and microscopic pieces of a magnetic material made of neodymium, iron and boron.

"The researchers also used a stronger field to yank the particles upwards, making the robot jump"

When solid, the material was strong enough to support an object 30 times its own mass. To make it soften, stretch, move or melt into a crawling puddle as needed for different tasks, the researchers put it near magnets. The magnets' customised magnetic fields exerted forces on the tiny magnetic pieces in the robot, moving them and deforming the surrounding metal in different directions.

For instance, the team stretched the robot by applying a magnetic field that pulled these granules in multiple directions. The researchers also used a stronger field to yank the particles upwards, making the robot jump.

When Majidi and his colleagues used an alternating magnetic field – one whose shape changes predictably over time – electrons in the robot's liquid metal formed electric currents. The coursing of these currents through the robot's body heated it up and eventually made it melt (*Matter*, doi.org/grpm6z).

"No other material I know of is this good at changing its stiffness this much," says Majidi.

Exploiting this flexibility, the team made two robots carry and solder a small light bulb onto a circuit board. When they reached their target, the robots simply melted over the light bulb's edges to fuse it to the board. Electricity could then run through their liquid metal bodies and illuminate the light bulb.

This robot escaped its cage by melting and seeping out

WANG AND PAN ET AL.

In an experiment inside an artificial stomach, the researchers applied another set of magnetic fields to make the robot approach an object, melt over it and drag it out.

Finally, they shaped the robot like a Lego minifigure, then helped it escape from a cage by liquefying it and making it flow out between the bars. Once the robot puddle dribbled into a mould, it set back into its original, solid shape.

The robots could be used for emergency fixes in situations where human or traditional robotic hands become impractical, says Li Zhang at the Chinese University of Hong Kong. For example, a liquefied robot might replace a lost screw on a spacecraft by flowing into its place and then solidifying, he says. ▮

Physics

No-flicker flames could make engines more efficient

FLAMES that don't flicker could make engines and stoves more efficient, but creating them usually requires artificially low gravity or pressure. Now, researchers have manged to do it in real-world conditions by pairing flames together.

Devices ranging from stoves and furnaces to aircraft and spacecraft engines use tightly arranged flames. When flames are close together this increases the amount they flicker. That, in turn, can make the devices less efficient or produce more pollutants, says Xiaoyu Ju at the University of California, Berkeley.

Ju and his colleagues set out to investigate whether flame flickering can be prevented by continuously changing the distance between the flames under standard conditions on Earth. In the past, producing non-flickering flames had required using aircraft where motion lowers gravity or in laboratory set-ups with precisely controlled pressure.

The researchers used two identical methane gas burners. The left-most burner couldn't move, but they fixed the right-most one to a platform that oscillated to the left and right. They recorded both flames with a high-speed camera.

"Unstable combustion not only makes an engine inefficient, but also may put it at risk of failure"

From previous studies, the researchers knew that there was a critical distance between the flames where both would momentarily stop flickering. Their recordings showed that once one flame was put into motion, flickering could be stopped for hundreds of milliseconds at a time.

When the two flames were closer than the critical distance they behaved almost as one, waving and flickering in unison. When they were further apart than the critical distance they wiggled in opposite directions. However, when the platform carrying the right-most flame was programmed to keep moving so that this flame was always just slightly off from the critical distance, the recordings showed both flames burning without moving or breaking up for up to 0.84 seconds at a time (*Physical Review Applied*, doi.org/jt8t). Ju says that instead of influencing each other, the flames would get stuck in a "coupled but not yet coupled" state.

Peng Zhang at the City University of Hong Kong says this experiment could be used as a starting point for investigating how gas-turbine engines in aircraft could be made even more stable and reliable. "Unstable combustion not only makes an engine inefficient, but also may put it at risk of failure." ▮

KPC

Taxing sugary drinks is no sweet solution New evidence supports sugar taxes as a way to reduce childhood obesity, but the issue is more complicated than it seems, says **Clare Wilson**

JUSTIN KASE Z12Z/ALAMY

Countries such as the UK and Mexico have imposed a tax on sugary drinks

SUGAR taxes work, according to a study published last week, so should more countries follow the likes of Mexico and South Africa in implementing one? Perhaps not.

Despite claims that the UK's tax prevents 5000 cases of obesity among 10 to 11-year-old girls in England every year, it is debatable whether any small drop in obesity rates in this age group is really due to the tax. Regardless, any such effect has been overwhelmed by the larger rise in children's weight amid the covid-19 pandemic.

Obesity rates have been increasing in nearly every country for decades. Many governments are considering or have brought in higher taxes on certain foods and drinks to nudge people into healthier diets. Sugary drinks are a common target, as they usually contain few other nutrients.

Mexico was one of the first countries to bring in such a tax, in 2014. The UK introduced one in 2018, causing some drinks to be reformulated with sweeteners to replace some of the sugar. Other places to have introduced similar drinks taxes include South Africa, Portugal and parts of the US, and there is fierce debate over whether to do so in Australia.

But do they reduce people's weight? In the latest study, Nina Rogers at the University of Cambridge and her colleagues say they have provided the first evidence that the UK rules have helped to stop some children from becoming obese.

Their analysis is based on a respected source of data: England's National Child Measurement Programme, which records the height and weight of most schoolchildren in their first and last years of primary school, when they are aged 4-5 and 10-11, respectively. Yet their conclusions hinge on estimating what obesity levels would have been without the tax, based on the existing trend of a gradual rise in obesity rates among 10 to 11-year-olds since about 2014.

The team's analysis suggests that, after about 2016 – when some drinks firms began reducing the sugar in their products in response to the tax announcement – the rise in obesity levels among girls of this age started to plateau. It finished at about 8 per cent lower in 2019 than it would have done if the previous trend had continued, the analysis found (*PLoS Medicine*, doi.org/grptgn).

But it seems unclear if this reduction can really be pinned on the sugar tax. Of the four cohorts studied – boys and girls, in the younger and older age groups – there was no apparent response to the tax in the other three groups. The researchers' claim therefore has the appearance of cherry-picking the figures that support their conclusions.

There are possible explanations for why only the older girls appear to have been affected, says Rogers. Younger children typically consume fewer soft drinks than older ones, so would be less affected by the tax, she says. On the other hand, UK boys tend to have more soft drinks than girls, so the sex difference doesn't fit that explanation, says Tom Sanders at King's College London.

The older girls might have responded more than the boys to negative publicity over sugary drinks in the media, says Rogers. She points out that a similar pattern of reduced obesity in teenage girls, but not boys, occurred after Mexico brought in its tax on sugary drinks.

Rogers also says that when the statistics for the older girls in England are broken down by income level, those from the lowest-income families had the biggest change in obesity levels from the predicted trend, and it is these families who typically consume more soft drinks.

Regardless of any trends before covid-19, childhood obesity levels in England jumped during the first year of the pandemic, according to government figures. This is probably because school closures meant children were more sedentary at home, with access to snacks.

Alarmingly, in the 2020 to 2021 school year, obesity rose from about 18 to 22 per cent in 10 to 11-year-old girls – an increase of 22 per cent on the previous year, swallowing up any theorised effects of the tax. In boys the same age, there was a jump of about 26 per cent.

Rogers says the effects of the lockdowns make it all the more important to consider expanding food taxes to include fruit juices and milk drinks. These are currently excluded from the UK sugar tax as they are considered to be more nutritious than soft drinks.

It is certainly true that more must be done to tackle the obesity epidemic – one of the world's biggest public health problems. But so far, it doesn't look like the evidence is there to support drinks taxes as an effective solution. ▮

10 to 11

Age of girls found to benefit from a UK tax on sugary drinks introduced in 2018

8%

Reduction in cases of obesity in this group in England in 2019 calculated as being due to the tax

22%

Year-on-year rise in obesity in this group amid the pandemic in the 2020 to 2021 school year

Neurology

How covid-19 affects the brain

The coronavirus can cause neurological symptoms. Research is starting to reveal how they occur and if they are treatable, reports **Michael Marshall**

FROM the first weeks of the covid-19 pandemic, it has been clear that the condition often causes neurological symptoms – ranging from headaches and brain fog to strokes and paralysis. We are now getting a clearer picture of covid-19's neurological symptoms and how the SARS-CoV-2 coronavirus indirectly affects the brain, pointing the way to potential treatments and raising questions about the effects that other viral infections may have on our brain.

"Neurological complications are also something that can affect people with mild covid-19 symptoms"

Covid-19 infections are commonly associated with neurological symptoms. Some studies have estimated that about 1 in 3 people with the infection will subsequently be diagnosed with a neurological or psychiatric condition. Common symptoms include loss of sense of smell, weakness and fatigue, headache, mood conditions like depression and cognitive difficulties such as memory loss. A small percentage of cases experience major neurological events like strokes and seizures. While neurological conditions are most likely to arise soon after infection, people who have had covid-19 remain at an elevated risk of developing one for up to two years afterwards.

The consequences can be serious. In a study published last year, Anna Cervantes-Arslanian at Boston University Chobanian & Avedisian School of Medicine in Massachusetts and her colleagues compiled data on 16,225 people hospitalised with covid-19. They found that 12.9 per cent of those studied developed serious neurological symptoms.

ALEJANDRO PAGNI/AFP VIA GETTY IMAGES

A person's sense of smell is tested near La Plata, Argentina, in May 2020

12.9%

of those with severe covid-19 get serious neurological symptoms

The most common was encephalopathy, an umbrella term that refers to general brain dysfunction, which can lead to altered mental states or delirium. All the symptoms analysed – which also included strokes, seizures and meningitis – were associated with worse outcomes: people who had them were more likely to need intensive care, to die during the study period and to have long-term symptoms if they survived.

Reduced blood flow

"This has been borne out in many studies," says Cervantes-Arslanian. "For people that are more seriously impacted in terms of neurologic conditions, their likelihood of surviving is lower and their likelihood of disability is very high."

In another 2022 study, Adam Hampshire at Imperial College London and his colleagues gave cognitive assessments to 46 people who survived after being hospitalised for severe covid-19. They found the participants were slower and gave less accurate answers in the assessment than people who hadn't been hospitalised with covid-19, and especially struggled with complex tasks like spatial planning and reasoning by analogy.

But it isn't just hospitalised patients who are affected. "Neurological complications are also something that impacts people that have mild covid," says Cervantes-Arslanian. People with the lingering symptoms dubbed long covid often complain of neurological issues such as brain fog. "I think a lot of the neurological symptoms are the most concerning [for people with long covid], because they provide a lot of disability," she says.

There is no single explanation for the neurological impacts of

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covid-19, but multiple mechanisms have been identified that may be involved.

One pathway could be the effect that SARS-CoV-2 can have on blood vessels and blood flow, causing indirect harm to the brain. In a study published last year, researchers including Laura Benjamin at University College London reviewed 83 studies of neurological symptoms associated with covid-19 and found that 26 per cent of cases included cerebrovascular events, such as strokes, in which part of the brain's blood supply is cut off. These events were associated with worse outcomes.

Inflammation

Another key factor is disruption to the immune system, which can affect the brain. Ed Needham at the University of Cambridge and his colleagues recently studied 175 people hospitalised with covid-19. Those with more severe illness – meaning they needed to be given oxygen or ventilation – showed higher levels in their blood of two proteins associated with brain injury. They also had higher levels of immune system molecules called cytokines, which promote inflammation, and of autoantibodies, which target their own body tissues rather than the virus.

"This is all, by its nature, observational," emphasises Needham. "It's definitely association rather than causation." But the implication is clear: rather than the virus directly harming the brain, the immune system's response to the virus could be doing damage by causing the brain to become inflamed. "We know from a myriad of other studies that systemic inflammation triggers neuroinflammation, and neuroinflammation is often detrimental and causes brain injury," says Needham.

These findings reflect a broader shift in immunological thinking. It had been thought that the brain was almost entirely cut off from the rest of the body behind the blood-brain barrier, so immune overactivation in the rest of the body wouldn't affect it. "The idea that you can have rampant systemic inflammation and your brain sits nicely cocooned away and it's not affected by it at all, I think is wrong and has been put to bed," says Needham.

There has also been a shift in thinking on the question of whether SARS-CoV-2 can enter the brain. Despite some early reports, many researchers had been sceptical because autopsies showed little or no evidence of the virus in the brain. However, it now seems clear that the virus does get in, at least in some cases.

One of the strongest data sets comes from a team led by Daniel Chertow at the National Institutes of Health in Bethesda, Maryland, which was published in December 2022. The researchers autopsied 44 people who died of covid-19, including 11 where they took multiple samples from the brain. They found SARS-CoV-2 in many tissues, including the brain, albeit often in low quantities.

Blood samples being analysed at a long covid clinic in Australia

LISA MAREE WILLIAMS/GETTY IMAGES

> **"Systemic inflammation triggers neuroinflammation and that can cause brain injury"**

Furthermore, they were able to grow the virus from the brain samples, showing that it was biologically active. "It is there and it is capable of replicating," says Chertow.

However, the viruses in these people's brains weren't associated with damage. "What we did not see is pathology that was attributable to viral infection," says Chertow. Nor did they find evidence of inflammation in the brain.

This aligns with other studies suggesting that SARS-CoV-2 infection in the brain may not cause significant harm. "Is it neuroinvasive? Yes, we've seen evidence of the virus in the brain," says Benjamin. But is the virus strongly attracted to brain cells and causing damage? "Not convincingly," she says.

Chertow's study highlights two uncertainties. The first is the extent to which viruses of any kind can persist in our bodies at low levels, long after the initial infection and when the acute illness has ended. Virologists generally believe that our bodies eliminate many viruses within a few weeks, says Chertow. But "clearly, there are opportunities" for them to linger on, he says.

The second uncertainty is whether a small number of virus particles can cause meaningful harm in the short or long term, or if there is a threshold below which they don't matter. "I don't think we know that," says Chertow.

Given this complex picture, it is perhaps no surprise that the best treatment for preventing neurological symptoms from covid-19 appears to be a mix of drugs. In a study published last year, researchers led by Ian Galea at the University of Southampton, UK, assessed neurological outcomes in patients given the anti-inflammatory drug dexamethasone, the antiviral drug remdesivir or both. The two individual medications helped, but combining them reduced neurological complications the most.

The immediate challenge is to find ways to rapidly determine the cause of neurological symptoms in each person, so that the most appropriate treatments can be given.

But to develop better treatments, we will first need a more detailed understanding of the two key questions covid-19 is raising about viral infections in general: how does being seriously ill harm our brains, and what do viruses do when they manage to get into them? ▮

Climate change

Earth's 'thermostat' can't save us

Rock weathering historically kept the climate stable, but it won't keep up with our emissions

Jason Arunn Murugesu

REACTIONS between rain and carbon dioxide in the atmosphere and rocks have helped to stabilise the climate throughout Earth's history, but won't prevent our emissions from causing severe warming, a study has concluded. However, the findings could help us devise better ways to trap CO_2 and slow climate change.

Over the course of Earth's history, greenhouse gas emissions from volcanoes should have led to much higher temperatures. Instead, the climate has remained relatively stable in that time, allowing liquid water to persist and life to flourish.

This stability is largely down to removal of CO_2 by the chemical weathering process, says Susan Brantley at Pennsylvania State University. In simple terms, this starts when CO_2 gas reacts with rainwater to form carbonic acid, which dissolves rock such as limestone. This rock erosion leads to the production of soluble minerals and bicarbonate, a dissolved form of carbon. These products are then washed into the oceans, where they form carbonate minerals that ultimately lock the carbon away in rock.

Previous studies have found that this chemical weathering may speed up in higher temperatures, taking more CO_2 out of the atmosphere and thus acting to control the climate, a bit like a thermostat. Brantley and her colleagues wanted to determine if this was true in all conditions.

The team looked at laboratory studies that detailed the chemical weathering process and compared these findings with field experiments measuring weathering rates in 45 soils from across the world. It has been difficult to reconcile lab data with that from the field, says Brantley, because lab studies can't accurately replicate weathering processes that take thousands of years in the real world.

Karst mountains in China formed by the weathering of limestone rocks

CARL NING/SHUTTERSTOCK

Combining all this data, the researchers were able to determine that chemical weathering is only particularly temperature-sensitive in areas with high rainfall and high rates of rock erosion due to this rainfall. This means that natural rock weathering is too slow to counteract the very large amounts of CO_2 being released by human activities (*Science*, doi.org/jtxg).

However, some scientists have proposed efforts to slow climate change by mining and grinding rock and laying it out on crop fields so that extra weathering occurs. The results suggest this idea, called enhanced rock weathering, may not be so outlandish. "To make it work in a big enough way you would have to mine a lot of rock and spread it over a very large area and make sure it's in an area with high rainfall," says Brantley. "But it might be one of the processes we use to slow down climate change."

This study is a big deal, says Penny King at the Australian National University in Canberra. "We now have a new idea that can be tested to explain weathering and this can help us with our goal to trap carbon dioxide in stable minerals," she says. ▮

Technology

ChatGPT can find and fix the bugs in computer code

A CHATBOT developed by tech company OpenAI can find and fix bugs in software just as well as standard machine learning approaches can – and beats them when aided by follow-up questions.

A number of tools exist that use artificial intelligence to check programming code to ensure there are no mistakes. Dominik Sobania at Johannes Gutenberg University in Mainz, Germany, and his colleagues sought to see how well ChatGPT could do this compared with other AI-powered coding support tools.

They first asked ChatGPT to answer questions taken from the QuixBug benchmark dataset, which is a series of small but challenging programming problems. For example, they gave the AI a small snippet of code and asked: "Does this program have a bug? How do you fix it?"

ChatGPT managed to correctly answer 19 out of 40 queries put to it – comparable with two other deep learning-based code fixing approaches, called CoCoNuT and Codex. That roughly 50 per cent success rate was considered state-of-the-art for such tools before ChatGPT.

The researchers then utilised ChatGPT's conversational interface to ask follow-up questions that a user would pose if they tried to insert the corrected code into a programming tool.

This approach highlighted where ChatGPT's solution was incorrect and meant that in 31 of the 40 queries, ChatGPT solved the issue (arXiv, doi.org/jtxf). "That was really surprising, because we haven't seen it before," says Sobania. "That's something new."

"Using this AI to correct code is a good idea, but we don't want to rely totally on it, as it isn't infallible"

Sobania expects ChatGPT or similar systems to be deployed as an additional troubleshooting tool for programmers in the future.

This is a good idea, but human oversight is still needed, says Alan Woodward at the University of Surrey in the UK. "We don't want to rely totally on the AI as it is not infallible." ▮

Chris Stokel-Walker

Health

Why ‘alcohol flush’ gene variant raises heart disease risk

Michael Le Page

AROUND 8 per cent of the world’s population has a gene variant that impairs the body’s ability to metabolise alcohol and causes unpleasant symptoms, such as flushing, soon after drinking. Now, researchers have shown why this _ALDH2*2_ mutation also raises the risk of heart disease.

The _ALDH2_ gene encodes one version of alcohol dehydrogenase, an enzyme that breaks down the toxic acetaldehydes produced when alcohol is metabolised and mops up other harmful substances called free radicals. The _ALDH2*2_ mutation stops the enzyme working.

Joseph Wu at Stanford University in California and his colleagues first analysed biobank data from Japan and the UK. They found that the risk of heart disease is four times higher in regular drinkers with _ALDH2*2_ than in those without the variant.

In volunteers, they then measured the ability of blood vessels to dilate. In people with the standard _ALDH2_ gene, this measure increases after drinking, but in those with _ALDH2*2_, it falls. This may seem odd given that people with _ALDH2*2_ flush when they drink, but the flushing is caused by the release of histamines, says Wu.

Next, they tested endothelial cells – which line blood vessels – derived from human stem cells. They found that cells with _ALDH2*2_ had higher levels of free radicals and inflammation than endothelial cells without the variant, and were less able to generate nitric oxide, which helps relax blood vessels. All these effects were exacerbated by exposing cells to alcohol (_Science Translational Medicine_, doi.org/grpszv).

For Wu, the take-home message is clear. “If you’re missing this enzyme, try not to drink. If you drink consistently, you are at much higher risk of heart disease, hypertension, diabetes and cancer.” ▮

Astronomy

Forbidden planet somehow escaped being eaten by star

Jonathan O’Callaghan

NASA/JPL-CALTECH

Illustration of 8 Ursae Minoris b orbiting its host star

A PLANET has been found sitting in an orbit where it should have been consumed when its host star expanded into a red giant, the same fate that may one day befall Earth.

Called 8 Ursae Minoris b, the planet is more than 500 light years from Earth and is a gas giant slightly larger than Jupiter. It orbits its star at about half the distance between Earth and the sun, completing this journey every 93 days.

Although the star has returned to a smaller size, it appears to have previously expanded into a red giant as it ran out of fuel – which should have destroyed the planet.

“Once low to intermediate-mass stars exhaust their hydrogen, they become red giants,” Marc Hon at the University of Hawaii told the 241st meeting of the American Astronomical Society in early January. “The star grows really big, and if you have a close-in planet, it’s doomed. The star will engulf the planet.”

While 8 Ursae Minoris b was discovered in 2015, follow-up work by Hon and his colleagues shows that the host star had already been a red giant and is now shrinking, a phase in which it is called a red clump star.

It would have expanded to reach about 70 per cent of the distance between Earth and the sun, which should have consumed 8 Ursae Minoris b in the process. “This planet is in a forbidden place,” he says.

93

The number of days 8 Ursae Minoris b takes to orbit its star

How the planet ended up there is a puzzle. One possibility is that it was originally further out in the system before being pulled in by the red giant as it expanded, but it is unclear why the planet would have stopped at its current location rather than continuing towards the star. “We disfavour such a process,” says Hon.

Another possibility is that the current star is the result of a merger between a pair of closely orbiting stars.

This could have prevented the red giant from expanding to the orbit of the planet, or might have created a debris disc that formed the planet following the red giant phase, making 8 Ursae Minoris b a rare example of a second-generation planet.

“We are very caught up with the idea of this being a binary system,” says Hon.

The merger would perhaps have been between a red giant and a white dwarf, which is the remnant core left behind after a star has expanded to become a red giant.

Survival questions

The finding is an “exciting result” that “raises questions about how the planet survived”, says Joleen Carlberg at the Space Telescope Science Institute in Baltimore, Maryland.

While planets have been found orbiting red giants before, they have been seen during the first stage, when the star is still growing in size. “If the planet gets too deep into the star, you expect it to be pulled apart,” says Carlberg.

The existence of 8 Ursae Minoris b could have implications for Earth, says Shreyas Vissapragada at the Harvard-Smithsonian Center for Astrophysics in Massachusetts.

While our planet could “fall into the sun” as our star expands, he says, it is also possible that it could survive, perhaps being pushed outwards as the solar wind removes mass from the expanding sun.

“We may have a shot,” says Vissapragada. “We all want to know how the story ends for our solar system.” ▮

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Infectious diseases

Bats swabbed for viruses

Researchers are hunting for pathogens that could jump into humans

Madeleine Cuff

OPEN wide! This fruit bat is being tested for diseases, including Ebola, that have the potential to infect humans. The check-up is part of an effort by conservationists and medical researchers to better understand the risk posed by the live trade of fruit bats and the consumption of bat meat in the Republic of the Congo.

Blood samples and nose and throat swabs were collected from around 100 fruit bats near the country's capital Brazzaville this month by researchers from the Wildlife Conservation Society and the Congolese Foundation for Medical Research.

The team sourced the bats from hunters who usually sell their catches in bushmeat markets around the city. None of the bats have so far tested positive for Ebola viruses, although fruit bats are known to harbour them and to have antibodies to the disease. ▮

CLÉMENT KOLOPP/WCS

Technology

Wi-Fi signals can show how you're standing

THE outline of a person's body can be worked out from the pattern of Wi-Fi signals moving across a room, which could help monitor older people at risk of hurting themselves if they fall or enable the detection of home intruders.

Indoor cameras and radar-based technologies can be used to detect a person's body shape or what position they are in, but these can introduce a privacy risk, such as a camera feed being hacked, or involve specialised hardware and installation.

Now, Fernando De la Torre and his colleagues at Carnegie Mellon University in Pittsburgh, Pennsylvania, have used indoor Wi-Fi to produce images of the shape of people's bodies.

"People might be a little freaked out now, in the sense that internet service providers might locate what people are doing at home, but, no, we are still not there," says De la Torre. "The only thing that this paper shows is that, in a very constrained setting… [with] three receivers of Wi-Fi signal, there is enough signal there for the fine-grained detection of human body parts."

To detect the body parts and where they are, the researchers placed three Wi-Fi transmitters and three receivers in different positions in a small room. When a person walks through the room, the presence of their body changes the pattern of the signal, which is recorded by the receivers (arxiv.org/abs/2301.00250).

The researchers then used a machine-learning algorithm, which had been trained on the relationship between Wi-Fi signals and visual images of a person's body shape, to decode these recorded Wi-Fi signals.

"It's like throwing out memory foam fibres into the whole room, and when we retract those fibres into a thread, our algorithm disentangles the fibres in the thread so that we can recover what the fibre has recorded," says team member Dong Huang.

> "It's like throwing out memory foam fibres into the room so we can recover what each fibre recorded"

The algorithm only works for the specific set-up it has been trained on, but De la Torre and his team hope it can be generalised to cope with real-world scenarios, where there might be interference from other Wi-Fi networks.

If it can be developed in this way, it could be used for monitoring to see if people in retirement homes have had a fall, for example. This is because it only requires two common Wi-Fi routers with three antennas each to replicate the number of antennas used in the study, says De la Torre. ▮

Alex Wilkins

Technology

Device can image heart as you run

A SMALL, flexible patch worn on the chest can create ultrasound images of the heart as people move. The first-of-its-kind device could help diagnose various medical conditions by imaging the heart during exercise.

Doctors currently do ultrasound imaging of the heart, called an echocardiogram, by placing a handheld device on the chest that sends and receives ultrasound. Hongjie Hu at the University of California, San Diego, says this is limited to before and after exercise, but monitoring during exercise could aid diagnoses.

So Hu and his team made a patch about the size of a postage stamp that converts electrical signals into vibrations to produce ultrasound waves. It also detects reflected ultrasound (*Nature*, doi.org/jtxc). **Clare Wilson**

Bionics

Synthetic skin better than the real thing

AN ARTIFICIAL skin is even better than human skin at sensing objects – detecting and identifying items it hasn't touched yet.

It is made of two outer layers of conductive fabric coated with nickel to serve as electrodes. These surround a porous sponge soaked in ionic liquid that acts as a conduit for electricity. The two layers act as a capacitor, storing electrical energy in an electric field.

The ions in the sponge boost the performance of the capacitor, which measures how much the distance between the electrodes changes. Its ability to detect tiny shifts is why this skin is able to sense it has touched something. It can also detect very small changes in the electric field around the skin, allowing it to tell when objects are near and what they are made of (*Small*, doi.org/jtxd). **Chris Stokel-Walker**

SHUTTERSTOCK/EVA BLANCO

Animal behaviour

Dogs can tell if we mean well or if we are teasing them

DOGS can understand when we are being genuine, even if they don't get what they want from us. Prior to this work, the ability to distinguish whether a person is unwilling or unable to perform a task had only been found in non-human primates.

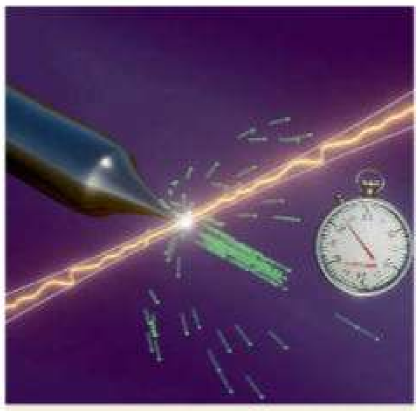
The close social bond between us and dogs is well established, but we had a limited understanding of if and how dogs comprehend human intent. To see if dogs can distinguish intentional and accidental actions by strangers, Christoph Völter at the University of Veterinary Medicine Vienna in Austria and his team ran tests with people offering dogs food while the body movements of the pets were tracked using cameras.

Each dog and human were separated by a transparent panel with holes that a slice of sausage could be passed through. In 96 trials of 48 dogs, participants either teased the dog by holding up and pulling back a treat, or they pretended to clumsily drop the piece of sausage on their own side of the panel before the dog could eat it.

In all trials, the dogs had to wait 30 seconds before finally getting their reward, during which the team tracked their reaction.

They found that when people pretended to drop a treat compared with when they intentionally pulled it away, the dogs responded more patiently: they made more eye contact with the experimenter, wagged their tails more and stayed closer to the barrier, suggesting they were still expecting a treat. Dogs that were teased sat, lay down and backed away from the barrier more frequently. The results were similar across different dog breeds, ages and sexes (*Proceedings of the Royal Society B: Biological Sciences*, doi.org/grpm7p). **Corryn Wetzel**

Really brief



ELEFTHERIOS GOULIELMAKIS/UNIVERSITY OF ROSTOCK

Electron pulse is shortest ever

Researchers have broken the record for the shortest pulse of electrons created, producing a signal just 53 attoseconds long – or 53 billionths of a billionth of a second. It could speed up computer chips and lead to microscopes that can capture sharp, stationary images at the atomic level (*Nature*, doi.org/grpqqn).

Preterm babies catch up with peers

Premature babies are often underweight compared with peers of the same age who are born at term, but by the time they reach 14 to 19 years of age, they have, on average, a similar body mass index. This is according to a study of more than 250,000 people (*PLoS Medicine*, doi.org/jtxk).

Monkey relatives lived in the Arctic

An analysis of fossilised teeth from Ellesmere Island in Canada reveals that extinct, squirrel-like, tree-dwelling relatives of primates lived in swampy forests in the Arctic 52 million years ago when the climate was about 13°C warmer than today (*PLoS One*, doi.org/grpnmm).

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Sally Adee finds a Greek tragedy can make great sci-fi p34

Comment

Altered images

Deepfakes are here to stay in film and TV. We need to accept that and deal with the legal and ethical implications, says **Bethan Ackerley**

MICHELLE D'URBANO

LAST week, UK streaming service ITVX unleashed a world first. It came in the form of a sketch show in which some of the world's biggest stars, from actor Idris Elba to climate campaigner Greta Thunberg, are reimagined as squabbling neighbours, drawing battle lines over communal gardens and Christmas decorations.

More significant than these quarrels between famous faces, though, is how those faces were created. *Deep Fake Neighbour Wars* takes the voices and bodies of impressionists, then marries them with digital versions of celebrity visages. Welcome to the first ever deepfake comedy.

I have started watching and I won't pretend it is must-see TV: the impersonations are patchy and the deepfakes, though technically solid, are somewhat uncanny. The level of realism also means the show has to pull its satirical punches, lest any litigious noses be put out of joint.

But the success of the underlying technology is clear, opening a can of worms about the future of deepfakes in television and film. It is a future that I believe can be positive, if we finally wrestle with the societal maladies that have led to deepfakes' misuse.

Entertainment companies are already using deepfakes for positive purposes. Last year, the makers of the film *Fall* used the tech to dub over sweary dialogue, avoiding costly reshoots and securing a US rating for younger audiences. Deepfakes have tackled language barriers in public awareness campaigns, such as in ads for a malaria charity in which David Beckham speaks in nine languages. They have helped conceal the identities of people in documentaries like *Hong Kong's Fight for Freedom*.

But there are real concerns about how they could be deployed, even when setting aside malicious applications, such as in deepfake porn that misappropriates facial images of well-known people. It is also easy to imagine, for instance, the tech taking work away from actors. Questions remain over how deepfakes affect performers' image rights – if they have them at all. "Image rights don't really exist in UK law. And even where they do, like in some US states, the devil is in the detail," says Lilian Edwards at Newcastle University, UK.

What is to stop a firm using a person's face without consent, provided it hasn't breached copyright? While some public figures have licensed their image rights for "legitimate" deepfakes, such as Bruce Willis and Snoop Dogg, ethical and legal norms around digital self-representation are far from established.

Things get even murkier when it comes to the dead. In 2021, the late food writer Anthony Bourdain's voice was deepfaked in the documentary *Roadrunner*, prompting condemnation from his friends and family, particularly as the film doesn't disclose that it uses this technology (unlike *Deep Fake Neighbour Wars*).

I can understand those who feel deepfakes' benefits will always be overshadowed by abuse. But we can't uninvent this technology and our attempts to control its use have lagged behind its growing sophistication. While we must lobby for laws around AI to keep pace with these developments, it is even more important we talk about how to use them ethically.

The most worrying applications all stem from deeper issues: the erosion of employment and privacy rights; hatred of women; a lack of media literacy; and of accountability for putting out misinformation. To tackle harmful deepfakes, we must remember that at the heart of this problem is a neutral tool that simply reflects humanity's evils back at us.

"It shines a light on inadequacies that are nothing to do with AI," says Andrew Rogoyski at the University of Sussex, UK. "So how do we solve that?" If you tune in to *Deep Fake Neighbour Wars*, this is the question you should ask yourself. ▮

Bethan Ackerley is *New Scientist*'s television columnist and a subeditor

Field notes from space-time

A matter of state Statistical mechanics helps relate the quantum world to objects that seem solid and not governed by observation, but questions remain, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

I RECENTLY walked by a physics department office that had a sticker on it saying something like "Heisenberg may or may not have been here". This is in part a nod to the quantum cat, which, while it is inside a box with no observer, may be dead or alive. We aren't sure until we look at it.

This feline thought experiment is intended to help us visualise a deep conceptual difficulty in quantum mechanics: the fact that the act of observing seems to determine what state matter is in. This is due to the probabilistic nature of quantum mechanics, and also the wave-particle duality I described in last month's column.

The mathematical structure that we use to describe quantum states of matter is an equation that describes waves. The wave equation, as it is known, requires a different way of thinking than what we are used to in classical, Newtonian mechanics. In the old picture, if we know the position, speed and direction of an object, we can use established laws of physics to calculate for certain what those properties will be in future.

Quantum mechanics, however, has a rule called Heisenberg's uncertainty principle: suddenly, we can't know the exact position and speed of an object simultaneously. We have to pick which one we want to be certain about. In addition to this uncertainty, the law that describes them in time is statistical in nature: we describe quantum objects using something called the wave function, which can be used to calculate probable values of position and speed, but we can never guarantee that those are the values we will measure.

So, there is a chance the cat is dead. There is a chance it is alive. But not all probabilities are created equal. Obviously, assuming the cat hasn't been in the box for an unreasonable period without air or sustenance, we can generally expect it to be alive. We know this from everyday life, and it is a certainty that we feel about many of the objects that we deal with routinely. This is because we live life on the scale of the macroscopic, not the microscopic, which is where the features of quantum mechanics are most evident.

This raises an obvious question: if quantum mechanics describes microscopic reality, why doesn't it also visibly govern macroscopic reality? And actually, we would still have a similar question even without the presence of quantum mechanics: even in the scenario where the objects behave classically, how do we describe their behaviour when they are all added together?

> "There is a chance the cat is dead. There is a chance it is alive. But not all probabilities are created equal"

The good news for both you and me is that I can – partially – answer this question with confidence. Here is the part that I do know: macroscopic objects are made up of lots of little microscopic objects. There is a whole subject that helps us calculate the properties of macroscopic objects based on their microscopic qualities, which is called statistical mechanics.

When I was a graduate student, one of my PhD advisers impressed upon me that statistical mechanics is one of the most important, if not the most important, subjects in all of physics. Roughly speaking, statistical mechanics is the mathematical framework that underpins thermodynamics and explains the relationship between measurable properties of matter, such as temperature, heat and pressure.

Stat mech, as we physicists call it, is a subject students learn both as undergraduates and as graduate students. But my early impression of it was that it is derivative and isn't fundamental, so I wasn't particularly impressed and didn't think it had earned its reputation as the "most important topic in all of physics". If it were so important, I would have heard about it before I went to college, right?

Now that I am older and much greyer, I am the professor walking around telling students that statistical mechanics is a central subject in physics. Not only does stat mech act as a connector between the very small and larger phenomena, but it also acts as an important bridge between quantum mechanics and the world of everyday life.

I did say I could only partially answer the question of how the quantum world relates to objects that seem solid and not governed by the whims of observation. Though quantum statistical mechanics helps us bring these wildly different scales of existence together, questions remain. For example, we experience space-time as smooth and continuous. But we now know that other phenomena that appear smooth and continuous on large scales are actually discrete – quantised – on small scales. Does space-time similarly have this property?

I don't know the answer, but I always assume there is a chance that the students I teach may be the ones to work it out. ▮

Chanda's week

What I'm reading
I'm very into Matthew Salesses's new novel The Sense of Wonder.

What I'm watching
I'm finally catching up on series two of McDonald & Dodds.

What I'm working on
Finishing up some new research papers that should be made public soon!

This column appears monthly. Up next week: Graham Lawton

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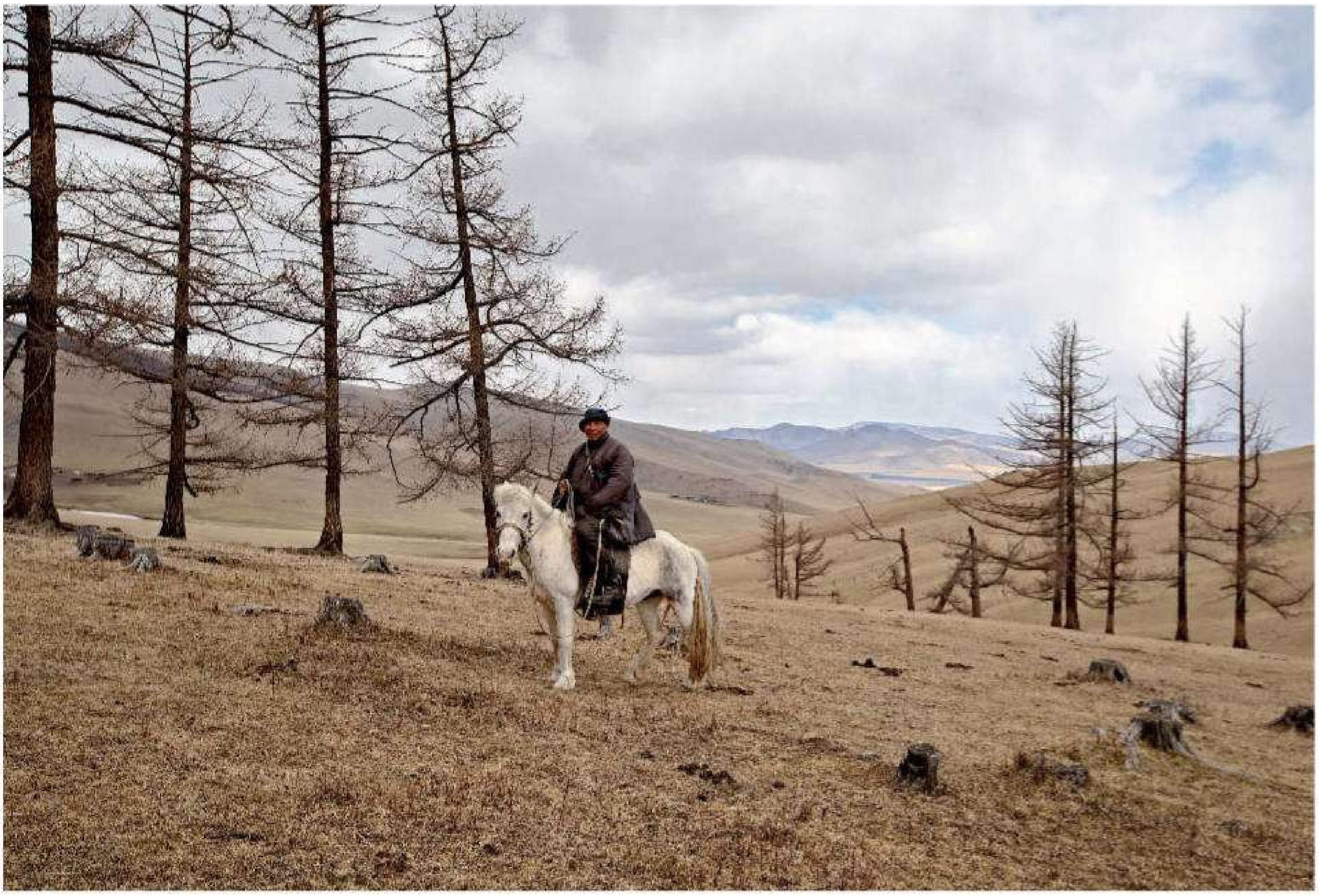
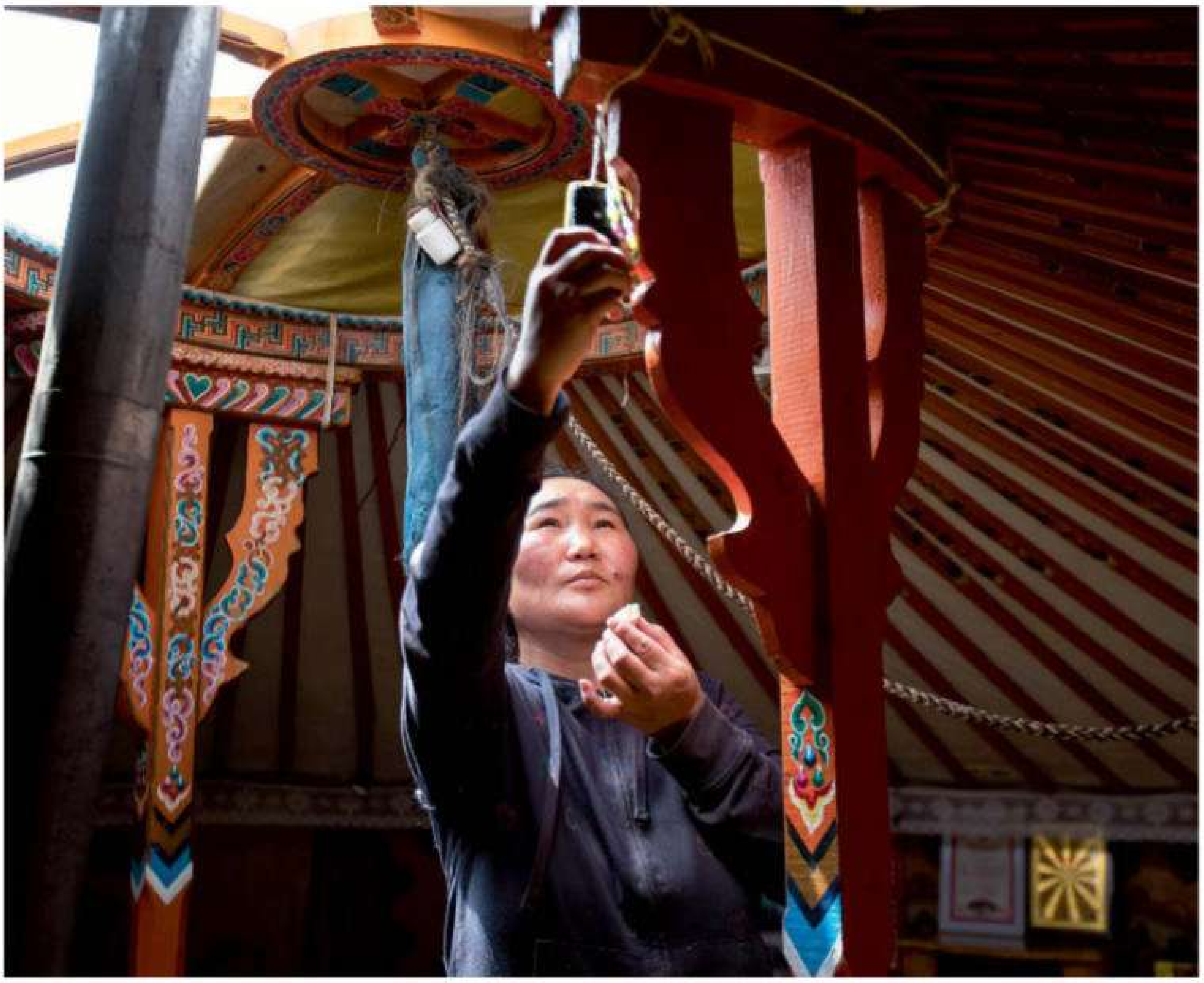


Clockwise from top left: Ganbaatar Davaasuren (known as "Bukhuu") in Uvurkhangai province, Mongolia; Bukhuu's 14-year-old son Mungun Huleg gathers the goats before selecting those that need to be combed that day; Tserennadmid Khaltarkhuu (right) cuts a baby goat's ears to mark them with the help of his children; Bukhuu's father Davaasuren Tsogt sits outside his ger (a traditional Mongolian dwelling); a herd of goats on a wall built from stones from the Gobi desert; Orkhontuya Oidovdagva answers the family mobile phone from the centre of a ger, where the phone is left to hang all day. **Centre:** A goat is combed.



Woolly jumpers

Photographer Matilde Gattoni

FORTY per cent of the world's cashmere is sourced from the windswept plateau of Mongolia.

The fabric is made from the undercoats of the local goats, which develop a particularly tight fur to survive the harsh winters, where temperatures can drop as low as -40°C. In past decades, cashmere has made a fortune for local herders, becoming the main source of income for a third of the Mongolian population.

But lately climate change and overproduction have threatened the cashmere supply, and a unique way of life with it. In Mongolia, temperatures have warmed by more than 2°C in the past 80 years, above the world average, and could rise by up to 5°C by the end of the century. Milder winters – which can negatively affect the quality of cashmere – are now followed by long, dry springs and short summers, when not enough rain falls to sustain the pastures.

The global cashmere boom saw the number of goats skyrocket from 10.2 million to 26.5 million, causing overgrazing and desertification. Seventy per cent of Mongolia's pastures are already considered degraded.

To address the problem, local herders are reviving traditional pastureland management practices. Cooperatives have also been set up to coordinate grazing and rotation between pastures, to give nature the chance to replenish itself, and the national government has imposed a tax on livestock to curb numbers.

But so far, no alternative source of income seems a ready substitute to a fabric that has provided an economic lifeline for a nomadic way of life that would otherwise have been lost. ▮

Matteo Fagotto

Editor's pick

Unlikely, extreme climate outcomes are still possible

14 January, p 28

From Spencer Weart, Hastings-on-Hudson, New York, US

Graham Lawton does well to point out that a civilisation-destroying climate catastrophe with warming of 4°C to 5°C, also known as the "business as usual" scenario, is no longer the most likely outcome, if indeed it ever was.

However, as he acknowledges, there is much uncertainty in our understanding of the climate system. Assessments say that, under current global policies, the most likely rise by 2100 will be about 2.7°C. But that is only the midpoint of a range, with a roughly 5 per cent risk that the rise will go somewhere above 3.5°C.

If we get that much heating, it would still be hard to sustain an even partially prosperous and liberal civilisation. Faced with this all-too-plausible risk, the world needs to accelerate its efforts. As a noted climatologist once said: "Nobody would board an aircraft with a 5 per cent risk of crashing."

Why a space sunshade isn't such a bright idea

7 January, p 38

From Arthur Dahl, president of the International Environment Forum, Geneva, Switzerland

There is a fundamental contradiction between two of Vaclav Smil's innovations to save humanity. He calls for more efficient photosynthesis, while also suggesting the need for a planetary sunshade to control global warming.

However, such geoengineering wouldn't only cool Earth, but also reduce the efficiency of photosynthesis at the global level. We are already destroying much of the photosynthetic capacity of the planet through deforestation, changes in land use and impacts on ocean phytoplankton. A tipping point where the energy captured by photosynthesis is no longer sufficient to support all life may be closer than we think.

New web may be a great opportunity for predators

21 January, p46

From Ron Dippold, San Diego, California, US

There is nothing democratising about web3, which runs on the blockchain, the technology that underpins cryptocurrencies. It is about replacing control of the web by giant tech corporations with possible future control of it by criminals and feudal lords.

And, as with cryptocurrencies, you would trade ownership of the web by giant amoral corporations, who are at least interested in minimising fraud, for ownership by a much wider base, possibly one that would include many amoral individuals who are only interested in obtaining your money by whatever means possible, criminal if necessary. If you think web 2.0 is unsafe, you have seen nothing yet.

Precedent for rethinking the pre-op fluid rule

21 January, p 27

From John Davies, Lancaster, UK

Clare Wilson reports on challenges to the "nil by mouth" rule that patients shouldn't consume liquids for 2 hours before surgery. It is surprising how entrenched medical practices can be!

However, she might like to know that, more than 30 years ago, women were allowed to drink and to suck sweets during labour, despite the increased acidity and resting volume of their stomach contents and the risk that they might require anaesthesia.

For general anaesthesia, they would routinely be given a "rapid sequence induction" in which the oesophagus would be compressed by pressure on the cricoid cartilage of the larynx to prevent reflux and lung contamination, and the trachea would be intubated to exclude any refluxed acid thereafter. This policy had been shown to be safe and effective.

If it looks like animal fun, then it probably is fun

14 January, p 27

From David Matheson, Northampton, UK

Marlene Zuk warns against attributing feelings to non-human animals that are more commonly ascribed to us, saying it is stifling inquiry. It appears that the notion that any non-human might have fun is something of an anathema.

Just as we can't know what goes on in a pre-verbal toddler's head when they seem to be having fun, we can never understand what goes on in a non-human's head when it appears to be doing the same. We can, however, identify behaviours consistent with fun. If it looks like fun and has any other necessary attributes of fun, chances are it is some sort of fun.

In defence of guidance for cutting Alzheimer's risk

28 January, p 19

From Professor Jonathan Schott, UCL/Alzheimer's Research UK (plus four more signatories – see online)

We are concerned your coverage of Alzheimer's Research UK's Think Brain Health campaign will undermine a vital initiative to raise awareness of widely accepted modifiable dementia risk factors.

Your article is critical that evidence for dementia prevention comes chiefly from observational studies rather than randomised controlled trials (RCTs).

For many exposures associated with dementia, such as smoking, diet and air pollution, RCTs are either impossible, unethical or impractical. The implication that observational studies are intrinsically flawed also misunderstands high-quality medical evidence. Standards for observational studies of causation exist and have generally been followed when gauging dementia risk. Also, a review by Cochrane, a body that assesses health research quality, found "little evidence for significant effect estimate differences between observational studies and RCTs".

Public health is about prevention using the best available evidence, which is what the Think Brain Health campaign aims to do.

Beyond experience and beyond imagination too

14 January, p 42

From John Davnall, Manchester, UK

Your look at the limits of knowledge asks us to imagine a woman who has been brought up in a black, white and grey room, so that everything she sees is in monochrome. She studies colour in the abstract, then goes out to witness a polychromatic world. This is used to exemplify that some knowledge can only truly be gained by direct experience.

Now, think of all human knowledge as bounded by our experiences and our deductions from them. Is there stuff of some unknowable nature out there, which neither our experiences nor powers of abstract thought can ever hope to touch?

I repeat a question that I asked in your pages some years ago: could a life form deprived of sensations resulting from electromagnetic radiation discover the theory of relativity? We don't know what sensations we are deprived of.

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The net tightens

The chilling story of the world's most powerful spyware program should teach us that no one is safe from such systems. But will it, asks **Simon Ings**

Book

Pegasus

Laurent Richard and Sandrine Rigaud

Macmillan

EDWARD SNOWDEN's 2013 leaks from the US National Security Agency triggered a global debate around state surveillance – but even he couldn't quite believe the scale of the story described to him in the summer of 2021.

Whistle-blowers had handed French investigative journalists Laurent Richard and Sandrine Rigaud a list of 50,000 phone numbers. These belonged to people flagged for attack by a cybersurveillance software package called Pegasus.

The investigation that followed is the subject of *Pegasus: The story of the world's most dangerous spyware*, a non-fiction thriller and a must-read for all, not just those interested in cryptography and communications. As the authors warn: "Regular civilians being targeted with military-grade surveillance weapons – against their will, against their knowledge, and with no recourse – is a dystopian future we really are careening toward if we don't understand this threat and move to stop it."

Pegasus offers a fascinating insight into how journalism is coping with a hyper-connected world. Eyewitnesses and whistle-blowers have better access than ever to sympathetic campaigning journalists worldwide. But this advantage is shared with the very governments, corporations and organised crime networks that want to silence them.

To drag Pegasus into the light, Richard's Forbidden Stories consortium choreographed the activities of more than 80 investigative journalists from 17 media organisations working across four continents and in eight languages. The consortium's mission is to continue and publish the work of other journalists facing threats, prison or murder.

HENRIQUE CASINHAS/SOPA IMAGES/ZUMA WIRE/ALAMY

LUDOVIC MARIN/AFP VIA GETTY IMAGES

Whistle-blower Edward Snowden (above) and French president Emmanuel Macron (right)

Its Pegasus investigation started in March 2021, knowing full well that it had to conclude by June that year. By then, NSO – the Israeli company that created Pegasus in 2016 – was bound to twig that its brainchild was being hacked.

The bigger the names linked by the consortium to that list of phone numbers, the harder it would be to keep the investigation under wraps. Early on, the name of a journalist called Jorge Carrasco cropped up. He led in one of the consortium's other cross-border collaborations, which aimed to finish the investigations of murdered Mexican journalist Regina Martínez. Then things got silly: the names of half the French cabinet appeared. Then president Emmanuel Macron.

> **"Pegasus gains free rein on a mobile device, without ever tipping off the owner to its presence"**

In a pulse-accelerating account that is never afraid to dip into well-crafted technical detail, the authors explain how Pegasus gains free rein on a mobile device without ever tipping off the owner to its presence. It turns out to have evolved out of software designed to serve consumers waiting in queues on tech support call lines.

Shalev Hulio and Omri Lavie, two of the founders of NSO, cut their teeth developing programs that allowed support technicians to take charge of a caller's phone.

Before long, a European intelligence service came calling. Eventually, Pegasus was sold to more than 60 clients in over 40 countries. It was the first software to give security services an edge over terrorists, criminal gangs and paedophiles – and over whistle-blowers, campaigners, political opponents, journalists and at least one Emirati princess struggling for custody of her children.

This book isn't a diatribe against the necessary (or at any rate ubiquitous) business of government surveillance and espionage. It is about how, in the contest between ordinary people and the powerful, software is tilting the field wildly in the latter's favour.

The international journalistic collaboration that was the Pegasus Project sparked the biggest global surveillance scandal since Snowden. It led to a European Parliament inquiry into government spyware, legal action from major tech companies, government sanctions against NSO and countless individual legal complaints.

But the authors spend little time sitting on their laurels. Demand for such systems is only growing, with certain governments making offers to certain tech firms that add zeroes to the fees NSO enjoyed. Nor do the authors expect much from the public debate sparked by their investigation: "The issues... might have been raised," they concede, "but the solutions are not even in the works." ▮

Simon Ings is a writer based in London

A modern guide to sex

An authoritative yet user-friendly sexual behaviours manual is welcome. Shame about the lack of sex appeal, says **Elle Hunt**

Book

Impulse: The science of sex and desire

Jon Grant and Samuel Chamberlain

Cambridge University Press

LET'S talk about sex – or not. Many of us have trouble striking the right tone or even finding the right words, caught between obfuscating with the birds and the bees or titillating with undue detail. For the topics too awkward to raise in person, there is always the internet, but its answers are many and highly variable.

Factor in the pernicious moralising and social taboos still pervading discussions of sex, and credible, non-judgemental sources of information become a valuable resource – if only to reassure you that, yes, you are normal.

Impulse is billed as a practical, "go-to guide" to the questions and queries about sex that everyone would like answered. Co-authors Samuel Chamberlain, a psychiatrist at the University of Southampton in the UK, and Jon Grant, a psychiatrist and behavioural neuroscientist at the University of Chicago, study compulsive sexual behaviour and related conditions. Here they bring together their own findings and others. As they note, the stakes are high: "If we know so little about sex, how do we know if and when sexual desire is typical or healthy?"

Everyone has a question about sex they would like answered – even if it is just "am I normal?"

The user-friendly focus is clear from the chapter headings, which identify common issues, much like the table of contents of a home repairs manual: too little sex; too much sex; developmental issues and sex; drink, drugs and sex; or digital technology and sex. Each is an even-handed exploration of the predilections and pressures often at play, with a view to demystifying the murky mechanics of desire.

The combination of scientific studies and clinical experience, plus cultural analysis, is effective at unpicking the myriad influences on our individual sexual desires and society's role in shaping them, and makes clear the need for a nuanced understanding of sexual behaviours deemed excessive or risky.

It is easy to imagine some of this authoritative advice and patient, big-picture contextualisation being transformative for readers struggling with unnecessary shame – or at least a step in the right direction. For example, the authors dismiss the social taboo that masturbation is "sinful" or perverse, and even justify the suggestion that it could be healthy, referencing a study that found a link between more frequent ejaculation and a lower risk of prostate cancer.

Even for those who understand that it is normal for sexual appetites to differ within couples and perhaps fluctuate over time, *Impulse* can provide friendly reassurance.

Although Chamberlain and Grant's overview of sexual behaviours and common problems is wide-ranging, lack of space can make it seem a bit perfunctory in places. For example, the chapter on physical health is dealt with in short sections covering areas like "sex and mental health" or "sex and heart problems". Inevitably, these would be of vastly different interest to individual readers who might prefer a more in-depth look at one or the other.

Between the subheadings, summaries and reliance on rhetorical questions, *Impulse* functions more as a user manual than a work of non-fiction. Even the anonymised case studies can be too generalised or improbable to be illustrative. I particularly struggled with 21-year-old nursing student "Audrey", who has "never taken it to the 'next level' with" the "young men she has dated occasionally" and "wonders if there are any positive benefits of sex, rather than it being 'all bad' or just for the purposes of having children".

If someone has a specific basic query, or is in need of particular reassurance or knowledge, *Impulse* is an authoritative addition to the shelf – but we could be forgiven for wanting a little more sex appeal. ▮

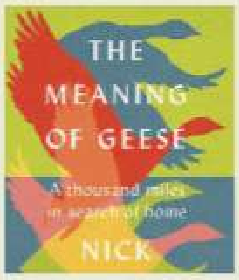
BEATRIZ VERA/SHUTTERSTOCK

Elle Hunt is a writer based in Norfolk, UK

Don't miss

Listen

Innervate is an EP by composer Liza Bec (pictured), who almost lost their performance career to a rare epilepsy triggered by playing music. The EP spotlights the roborecorder, an instrument they built. On release 10 February.



Read

The Meaning of Geese is teased out by Nick Acheson, whose epic bicycle adventures trace the incoming paths of pink-footed and brent geese as they arrive from Iceland and Siberia to fill the skies of his native Norfolk, UK. On sale from 9 February.

Visit

Drug experiments and forays into medicines, narcotics and everyday cravings are the focus of a free event that brings experts together to explore the science of drugs. At Imperial College London on 9 February at 6pm GMT.

LOWER: DAN WEILL; UPPER: BEN HUGHES

The sci-fi column

In the footsteps of giants

Arch-Conspirator sees Veronica Roth retell Sophocles's 2500-year-old Greek tragedy *Antigone* as a deceptively simple slice of science fiction. The result reminds us that human nature is timeless, says **Sally Adee**

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee

Book

Arch-Conspirator

Veronica Roth

Tor

Sally also recommends...

Book

Hopeland

Ian McDonald

If you are after escapism rather than analysis, try cityscapes filled with weird electrical magic and strange underground worlds. It is all very Neil Gaiman and hooks you in from the first page.

GREMLIN/GETTY IMAGES

In an unnamed dystopia, citizens face dangerous reproductive rules

THERE isn't much world-building in Veronica Roth's sci-fi retelling of Sophocles's classic Greek tragedy *Antigone*. Then again, in *Arch-Conspirator*, there isn't much world. A dusty dystopian city (Thebes in the original, but it isn't clear where we are in the reboot) is all that remains after a thinly sketched environmental polycrisis has turned humanity into an endangered species.

Or, at least, that is what a reader surmises. The citizens don't seem to know much about the arid wilderness outside their city's limits, apart from the fact that no one has come back from it alive. There is no mention of long-range transportation like planes or trains. And blue sky is a rare sight from beneath a poisoned cloud cover.

While it would be possible to get information from "the old internet" (accessible in dusty shops that sell odds and ends), few bother. Roth's claustrophobic details paint a picture of an island in space and time: the inability to see beyond your immediate environs is very much the point.

But the technological backslide hasn't been complete. Among the few reminders of humanity's peak is the Archive, a massive Parthenon-like library filled with our species' store of heavily edited genetic material – the "ichor".

This is now the only acceptable method of reproduction, after a viral pandemic has disfigured the human genome so that, unless it is edited extensively, an individual's DNA will begin to deteriorate from birth. The old-fashioned way of making babies is now taboo.

> **"For this last scrap of humanity to survive, everyone must obey the draconian rules"**

The new system has turned women into slaves of the state, even though each forced birth carries a 50 per cent risk of death. The rationale is that, for this last scrap of humanity to survive until Earth can accommodate the species again, everyone must be fastidious in obeying the new draconian rules.

Kreon, who enforces them, is a fascist who seized control in a coup that killed Antigone's father, Oedipus. In a clever nod to her original backstory, in which she was conceived from the sinful union of Oedipus and his mother, Roth's Antigone is stained because she was conceived in the old way. Putting his needs over society's is what got Oedipus killed, and it drives the rest of the fast, inevitable plot as his children vow revenge.

Contrary to what a reader might expect from Roth's popular young-adult series, *Divergent*, her new book doesn't traffic in easy answers. How do you govern a civilisation in decline? This question would have weighed heavily on Sophocles, who witnessed the collapse of the Athenian empire. A declining state strains the balance between the individual and their society. Fascist rule may preserve things by putting society's needs before those of the individual; equally, a society that does the opposite collapses into a messier version of the same authoritarianism.

Roth could hardly have chosen a more timely tragedy to explore. It isn't clear to me whether this book seems so relevant because the feeling of doom is a feature of many similar periods in history, or whether a retelling of *Antigone* feels particularly apposite because we are really living at the end of something. Either way, it is a great time to go back to the Greeks.

Without giving too much away, Roth's ending offers more hope than Sophocles's grief-burger. Not much, mind you. But it does leave the thinnest possibility that the benighted citizens of this dystopia might be missing the big picture. ▮

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IMMUNE SPECIAL

Unleash your immunity

IMMUNOLOGISTS are making extraordinary progress in their attempts to understand our immune system – the intricate constellation of cells and molecules inside our bodies that defends us against bacteria, viruses, fungi and toxins.

Over the next eight pages, we delve into some of the very latest science to find out everything from what foods you should eat to best boost your immune system to why some people never seem to get sick.

VICKI TURNER

HOW TO TELL WHETHER YOUR IMMUNE SYSTEM IS HEALTHY OR NOT

WHEN you are under the covers, sniffling from your third cold of the year, you might wonder whether your immune system is pulling its weight. It is a question we would all love to answer: is our immune system healthy or not? Now, a burgeoning field of immunology is attempting to do just that with tests that "grade" your immune system, the idea being that it could help people preempt problems and motivate them to make lifestyle changes to avoid ill health.

To understand how healthy your immune system really is, let alone improve it, first it is helpful to get to grips with what it actually does. Consider it your internal army, with different units coordinating to eliminate enemy invaders, all while avoiding collateral damage to your own tissues and constantly adapting to new challenges.

Like a real army, your immune system can also fall into disarray, with some units underperforming while others go rogue. This can cause major illnesses.

So how do you tell whether your army is doing its best? Let's begin by considering the different components. The first line of defence comes from innate immune cells such as macrophages, which engulf bacteria and release chemicals that trigger inflammation, making cells less hospitable to pathogens (see "Get to know your immune system", page 42).

Once a threat has been identified, a second line of defence called the adaptive immune system kicks in, with more specialised tools. B-cells, for example, form antibodies that bind to the unwanted newcomer and render it harmless. T-cells, meanwhile, include killer cells that attack infected cells, as well as helper cells that coordinate the activities of the other immune cells and aid the B-cells in producing antibodies. Regulatory T-cells are also on hand to call off the battle when the threat has passed, so the body can repair the damage.

Our biological warriors can be found lurking around the body. "They're in the mucosal lining of our airways, the digestive tract and in our skin – anywhere things that could upset the body might get in," says Jenna Macciochi, an immunologist at the University of Sussex, UK.

They are also aided by microorganisms in the body, known as the microbiome. "We often think about the microbiome in relation to the gut, but we have microbiota living all over our body," says Macciochi.

When we are at peak health, these different components are perfectly balanced – but there are ways that things might go awry. You may lack the friendly microbes that protect your digestive system, meaning you are more susceptible to gut infections. A bad diet or stress can make you more sluggish at producing the correct immune cells to fight infection, and after you have recovered, you might lose the cells that "remember" the pathogen, should you be exposed again. Since the immune system can also spot and remove tumours, underactivity can render you more susceptible to cancer.

Other problems arise from overactivity, when the immune system begins acting with disproportionate force, leading it to harm the body. For example, the immune system may become oversensitive to foreign bodies, such as pollen, that don't pose an actual threat, which leads to allergies. Or it might start attacking its own organs, resulting in autoimmune diseases. Even muted immune activity for long periods of time, such as low-grade inflammation, can be harmful and is thought to contribute to everything from cardiovascular disease to depression.

Historically, there are some basic ways to assess the health of your immune system – including, for instance, measuring the levels of inflammatory molecules and numbers of immune cells within your blood. But recently, our measures have become more sophisticated, with a greater focus on

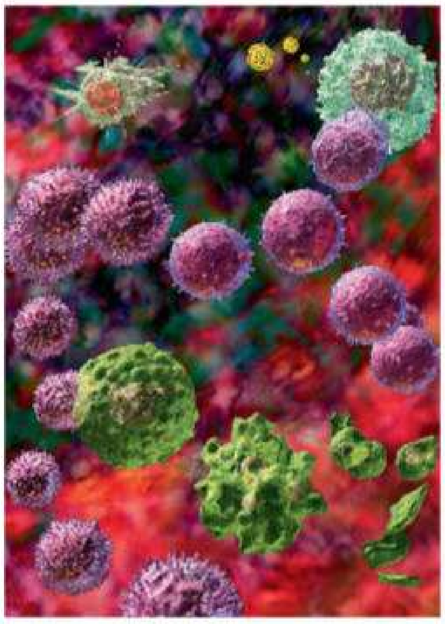
"A bad diet or stress can make you more sluggish at producing the correct immune cells to fight infection" examining the precise balance of the immune system's different components.

Sunil Ahuja's team at the University of Texas Health Science Center, for example, has designed a way to classify people's "immune grade" based on the relative levels of different T-cells. People with higher-than-average numbers of helper T-cells, combined with lower levels of killer T-cells, had the highest immune grade, according to their classification. The team has shown that people with immune grade I tend to have much better outcomes when they face a pathogen, with 88 per cent reduced mortality compared with those of lower grades after a covid-19 infection, for instance.

Importantly, the team's grades proved to be a better predictor for response to covid-19 than age alone, meaning that, in the future, this kind of measure may help to identify high-risk individuals with greater precision (see "How does your immune system change as you age?", page 43). "Even if you are 80, and you have a high immune grade, you'll do much better than someone much younger with a low immune grade," says Ahuja.

You may need to wait a while before your doctor is able to assess your health with this kind of precision, but you can get a good idea about the state of your immune system without any tests. As a general rule of thumb, Macciochi says that the average person should expect to have one or two mild illnesses a year. If you tend to become sick far more often, and if those infections tend to last much longer and are more severe than the people around you, then it may be a sign that one or more of the units in your immune army aren't functioning as they should. Your doctor should be your first port of call, but there are also things you can do to give your immunity a helping hand (see "What should you eat to boost your immune system?", page 41).

David Robson



RUSSELL KIGHTLEY/SCIENCE PHOTO LIBRARY

White blood cells can help to indicate immune health

WHAT EFFECT DID LOCKDOWNS HAVE ON CHILDREN'S IMMUNE SYSTEMS?

IT IS a question high in the minds of many parents and carers of infants born during the first years of the covid-19 pandemic: have lockdowns and social distancing had a long-term effect on babies' health? The good news is that these concerns are largely underpinned by misunderstandings over how the immune system is shaped during our first years of life.

It is clear that pandemic public health measures have had an impact on children's exposure to bacteria and viruses that cause illness. When strict social distancing rules were in place, the capacity for infections to spread was dramatically reduced.

An analysis of data from across England found that the number of children below the age of 15 admitted to hospital with influenza between March 2020 and June 2021 dropped by 94 per cent. It wasn't just flu that was affected: the analysis found reductions in child hospitalisations in 18 of the 19 infections they looked at, including mumps, measles, croup, tonsillitis and bronchiolitis.

Fewer infections

This leaves lockdown babies in a different position to the average infant. Typically, around 90 per cent of UK children have had an infection by the age of 1, for instance, but an analysis of babies born during Ireland's first lockdown found that less than half of 12-month-olds experienced any infections during their first year.

Fortunately, we don't actually need to get sick when we are very young. Infections like flu are more likely to lead to serious complications, such as pneumonia, in young children, especially those under the age of 2. "If you can avoid disease, it's better if you avoid it," says Nikolaos Papadopoulos at the University of Manchester, UK.

In recent months, the northern hemisphere has had a difficult winter in terms of seasonal infections, including among children. Lower population immunity is partly to blame for surging levels of illness caused by pathogens like the flu virus and RSV: because there were fewer cases of these illnesses during strict covid-19 measures, numbers are catching up now. This isn't a sign that children's immune systems have been weakened by lockdowns.

JEAN GAUMY/MAGNUM PHOTOS

The idea that it is important to get infections during infancy comes from the hygiene hypothesis, first proposed by epidemiologist David Strachan in 1989. The thinking was that life had become more hygienic, leading children to catch fewer infections, and that this predisposed them to develop allergies. But while the idea that young immune systems need to be "trained" on pathogens has taken hold in the public consciousness, the hygiene hypothesis isn't our best way of understanding immune systems in the modern age. What we really need in early life is to encounter a wide diversity of microbes – and not just the ones that are bad for you.

The ideal scenario, says Papadopoulos, is to be exposed "in very small quantities to many different types of microbes, viruses and bacteria, below the threshold for disease". So, rather than being a good thing in itself, getting ill is more of a marker that your child is encountering a range of microbes, good and bad. If you don't encounter many pathogens in your first years, that doesn't mean you will be less good at fighting them off later on, because your immune system continues to learn about diseases throughout life.

However, our early years do seem to be important for shaping our response to allergens, and a lack of exposure to diverse microbes during this time may make children more susceptible to allergies,

The number of children hospitalised for severe infections dropped in 2020-2021

asthma and some types of eczema. The Irish study found that lockdown babies were more likely to have atopic eczema and show signs of sensitisation to egg – the first step towards an allergy – although there was no increase in the proportion of children who actually had an egg allergy by the age of 1.

However, there are other ways we receive early microbial exposure than just socialising. Some, such as being born vaginally rather than by C-section, may not have been affected by the pandemic. Others, such as breastfeeding, spending time outside, antibiotic use and even living with a pet dog, may have been influenced by the way our lives changed in 2020 and 2021 – positively for some, negatively for others.

At the same time, while we know that all these factors seem to be linked to immune functioning, none of them has a strong enough effect to fully determine your immune future. It will be shaped by a complex interplay of personal circumstances, including genetics and many small and unique differences in the microbial environments in which we grow up. Which, thankfully, means there is no "right" way to train a young immune system.

Penny Sarchet

"The average person should expect one or two mild illnesses a year"

HOW TO TRAIN THE IMMUNE SYSTEM TO CURE SEVERE DISEASE

ONE of the most amazing things about the immune system is how hard it works without you even being aware. It not only fights off bacteria and viruses every day, it also kills off most cancers long before they become a threat. But sometimes cancers manage to dodge the immune system – and a number of cancer therapies rely on restoring its effectiveness. An emerging star is CAR T-cell therapy, which has produced dramatic results for some cancers when all the usual treatments have failed.

This incredible technology relies on T-cells, immune cells that patrol our body, killing infected or cancerous cells. T-cells detect their targets with a receptor that protrudes from their surface and binds to a target protein, or a displayed fragment of a protein, on the outside of other cells. What this means is that if you add the right receptor to T-cells, you can make them target anything you want, including a cancer.

To achieve this, a person's own T-cells are extracted and genetically modified to express a "chimeric antigen receptor". This artificial receptor is made up of three proteins, one that recognises the cancer cell target and two that boost the T-cells' activity.

Doctors multiply these cells and return them to their owner, where they seek out and destroy cells that have the target protein.

With a few of the first people treated still remaining free of cancer a decade later, it can now be said that, in some cases, CAR T-cell therapies can cure advanced cancers.

Unfortunately, this approach isn't a magic bullet. For starters, the immune attack on cancer cells it prompts can trigger potentially fatal side effects. What's more, CAR T-cells only work against blood cancers, not solid tumours, and only in a minority of people.

But there is hope. The technique is being improved. One big issue is that having to use each individual's own T-cells is extremely expensive, and with very ill people, it isn't always possible to extract enough T-cells. Donor T-cells see every cell in the recipient's body as foreign and start attacking them.

So, gene editing is now being used to knock out the genes involved in recognising cells as foreign, in addition to adding the receptor. These universal CAR T-cells can be used to treat many different people with the same cancers.

Leukaemia success

Another issue is that T-cells have an off switch on their surface called PD-1 to help prevent them attacking healthy cells. Some cancers thwart T-cell attacks by exploiting this switch. But if it is removed via gene editing, the T-cells can't be deactivated.

With standard gene editing, there is a limit to the number of changes that can be made. This is because each edit requires cutting DNA, which can kill cells or result in major mutations. But the latest CRISPR gene-editing tools don't cut DNA and so allow more changes to be made safely.

This approach was used last year to treat T-cell leukaemia for the first time. The 13-year-old who received the treatment had aggressive leukaemia that hadn't responded to any other therapy. Twenty-eight days later, tests revealed she was in remission.

Other teams are introducing even more ambitious changes to CAR T-cells in the hope of making them effective against solid tumours too. The use of CAR T-cells for treating infections by pathogens such as HIV and hepatitis C is also being explored. Furthermore, CAR T-cells are being used to treat autoimmune diseases by killing off the rogue immune cells responsible. Last year, a team in Germany reported that five people with lupus have remained free of the disease since being treated this way.

Genetically engineered immune cells are going to be a big part of our future. It is a future that looks very bright indeed.

Michael Le Page

ARE THERE SEX DIFFERENCES IN THE IMMUNE SYSTEM?

EZRA ACAYAN/GETTY IMAGES

Being male is a significant risk factor for severe covid-19

THE concept of "man flu" – the idea that men make too big a deal out of a cold – is an old joke. But when covid-19 arrived, we had to take a serious look at sex differences in how people respond to infections. Being male was a risk factor for experiencing more severe symptoms of the coronavirus: in England during 2020, men were about 60 per cent more likely to die from covid-19 than women. Men are also nearly twice as likely to be diagnosed with tuberculosis and slightly more likely to die from flu. So does your sex put you at an advantage or disadvantage when it comes to immunity?

There may be several reasons for immune sex differences. For one thing, we have discovered in recent years that oestrogen, the main female sex hormone, broadly stimulates immune system activity. The main male equivalent, testosterone, weakens it. But there are other forces at work too.

Sex is governed by DNA, which comes packaged up into 23 pairs of chromosomes. Most women have two X chromosomes, while most men have one X and one Y. To make sure that cells in female bodies don't have duplicate X chromosome genes in operation, one X is mostly disabled in every cell.

Genetic diversity

Which X chromosome is inactivated is determined randomly when embryos are a few weeks old. All the tissues in a female body are therefore mosaics, with half their cells using the X chromosome inherited from the mother and the rest using the one from the father. Because many genes involved in the immune system are located on the X chromosome, this means that female bodies have twice the genetic variation to call on when fighting infections. "Women have more diversity when it comes to individual genes," says Shäron Moalem, a genetic researcher based in New York.

In addition, not all the genes on the inactivated X chromosome are switched off, with some immune system genes remaining functional on both X chromosomes – including one called *toll-like receptor 7* (*TLR7*), which helps cells detect viruses. This means that most women have double the dose of *TLR7* in their immune system.

Having a stronger immune response is a double-edged sword, though: it may explain why women are more susceptible to autoimmune diseases, such as multiple sclerosis and rheumatoid arthritis, where the body starts to recognise its own cells as dangerous and attacks them.

Another contributor to this increased risk of autoimmune conditions, could be that the mechanisms to prevent autoimmunity work less well in female bodies, says Moalem. In the fetus, immune cells should be "trained" to recognise the body's own cells. Because most women are mosaics of two populations of genetically different cells, this training process may be less efficient.

On the other hand, women's greater propensity to autoimmunity helps them out when it comes to cancer, which arises when cells start multiplying out of control. The immune system is thought to destroy many tumours before they get big enough to be noticed (see "How to train the immune system to cure severe disease", page 39). Immune cells that aren't as well trained to recognise the body's own cells are more likely to attack them when they start looking different to normal, as tumour cells do.

There are also behavioural explanations for why women tend to get fewer cancers than men, such as men smoking and drinking more – but so much emphasis has been placed on these social factors, we have previously overlooked the immune sex differences, says Moalem. "The more we look, the more we find."

Clare Wilson

DO SOME PEOPLE HAVE NATURALLY STRONGER IMMUNE SYSTEMS?

WE ALL know that person. The one who rarely gets ill. The covid-19 pandemic highlighted that when it comes to catching circulating viruses and bacteria, we aren't all equal: some people can resist being infected by a pathogen even after heavy exposure. Finding out why could help keep the rest of us in better health.

A person may resist an illness because they have recently been exposed to the pathogen that causes it and their body knows how to fight it off. This wasn't the case for covid-19, as no one had encountered the coronavirus behind it before the end of 2019. Some people did seem to have some resistance to it, though, due to past infections with other, similar viruses – there are at least four coronaviruses that cause ordinary colds. In 2021, a few healthcare workers who had never tested positive for covid-19 despite heavy exposure were found to have had "abortive infections", when the virus briefly replicates inside the nose and airway before being wiped out. Their immune systems were found to react to an enzyme used by the virus that causes covid-19 as well as the cold-causing coronaviruses.

People may have resistance to infections because of their genetic make-up. For covid-19, this has been investigated in relation to people's risk of dying from or needing respiratory support due to their infection. Earlier this year, Johnathan Cooper-Knock at the University of Sheffield, UK, and his colleagues found more than 1300 genetic variants that are responsible for raising or decreasing an individual's risk of developing severe covid-19. Most affected the function of two types of immune cell: T-cells and natural killer cells (See "Get to know your immune system", page 44).

The same gene variants may explain why some people avoid catching it at all, says Cooper-Knock. But now that most people have been vaccinated against covid-19, factors that affect how well people respond to those vaccines may be more important, he says.

Other genes may be involved in our susceptibility to different pathogens. About 1 in 100 people with European ancestry are unlikely to be infected by HIV because of a genetic variant they have, which also affects T-cells. Another gene variant that affects a different kind of immune cell called a macrophage may alter the likelihood of developing tuberculosis, according to a study of an ethnically diverse sample of US people.

Given their benefits, why doesn't everyone have immune-boosting genes? The reason is that many genetic variants can have both beneficial and harmful effects. For instance, one gene variant became more common in the British population during the Middle Ages, probably because it boosted the immune response to the bacterium that caused the Black Death. But last year, it was discovered that this variant is now common in people with Crohn's disease. As with other autoimmune conditions, this is caused by the immune system mistakenly attacking the cells of our own body – in this case, the cells lining the gut.

Take this as a warning that while it may seem a good thing to try to supercharge the immune system, it is really balance that matters when it comes to providing the greatest overall protection.

Clare Wilson

WHAT SHOULD YOU EAT TO BOOST YOUR IMMUNE SYSTEM?

WALK down any supermarket aisle and you will see rows of food and drink that claim to help your immune system. We are told that cinnamon is good at battling inflammation and fighting off illness, for instance. The list of supposedly "immune boosting" foods also often includes berries, mushrooms, green tea, seeds, spinach, broccoli, probiotic yogurt and foods high in specific vitamins.

The problem is that when you dig deeper, you see that most of these bold claims aren't derived from clinical trials or solid science. More often than not, they are based on small lab experiments where chemical extracts of the plants, nuts or herbs are found to alter the potency of immune cells, and these findings rarely translate to anything useful.

So, what do we really need to eat to support a healthy immune response? Only fairly recently have we discovered that the biggest immune organ is our gut. The immune system is in regular contact with the trillions of microbes living in the gut, which send signals to dial immune activities up or down.

The good news is that the delicate balance of this system can be modified through diet. Take chronic low-grade inflammation, which can be thought of as the result of an overstimulated immune system and increases the risk of heart disease and metabolic problems such as obesity. The complex interactions between the gut lining, short chain fatty acids produced by the fermentation of dietary fibres by gut microbes, and pro-inflammatory chemicals called cytokines all contribute to our overall level of inflammation.

FOODS TO MAINTAIN A HEALTHY IMMUNE SYSTEM

1. Fermented foods, such as kimchi or kefir, which contain helpful probiotics.

2. Foods rich in a variety of fibre that provide nourishment for beneficial bacteria, such as leeks, onions, artichokes or cabbages.

3. Foods that dampen any inflammation after meals, such as green, leafy vegetables.

JAVARMAN/SHUTTERSTOCK

Artichokes are rich in fibre that feeds beneficial bacteria

Eat your veg

While anti-inflammatory diets are often promoted in vague terms by the nutrition industry, we do know that the composition of the gut microbiome can modify chronic inflammation and that diet has a role in this.

In recent years, my team and I at King's College London have been investigating this link between the microbiome and our diet in several ways. In the first part of our ZOE PREDICT (Personalized REsponses to DIetary Composition Trial) programme, we asked 1000 people with no known health problems to fill in a diet questionnaire and undergo blood tests. People who regularly ate a lot of vegetables had lower levels of circulating white blood cells. This resulted in lower levels of chronic inflammation and a lower risk of chronic diseases.

This positive impact of vegetables could be due to their high concentration of fibre and compounds called polyphenols, which act as prebiotics for our gut microbes, promoting the growth and activity of beneficial bacteria.

A healthy balance of gut microbes also seems to be helped by eating fermented foods, such as miso, kombucha and kimchi. These contain live microbes that can increase your gut microbiome diversity.

Strong evidence supporting specific types of fermented foods above others is still unavailable. However, we now know that the microbes from many fermented products make it past our stomach to our colon where bacteria reside. Although they only stay for a short while, they do have

›

“Immune-boosting foods are simply gut-friendly foods”

time to stimulate the production of helpful chemicals that aid our metabolism.

For the gut microbes to work optimally in supporting our immune health, we need a combination of regular probiotics – the bacteria themselves – plus a variety of good prebiotic foods for the microbes to ferment into helpful chemicals for us.

Foods to avoid are those that contain little or no fibre and cause rapid spikes in blood glucose levels as well as prolonged high blood fat levels after meals. These are associated with post-meal inflammation that can become chronic with repeated intake of sugary foods. Highly refined carbs and ultra-processed foods, especially those that contain cheap processed meats, are the biggest culprits. Artificial sweeteners and emulsifiers can also harm your gut microbes.

My take-home message is that the gut microbiome and our diets are closely linked, and both factors interact with our immune system in complex ways. “Immune boosting” foods, therefore, are simply gut-friendly foods: looking after your diet helps your gut microbes to help your immune system do its job.

Tim Spector

CAN WE CREATE AN ARTIFICIAL IMMUNE SYSTEM?

ONE of the most important features of the immune system is that it can learn and remember, a kind of biological intelligence that is rivalled only by the brain. And just like the brain, researchers are attempting to replicate this intelligence artificially, by creating an AI called Artificial Immunological Intelligence (AII) that will improve our understanding of the immune system and could be used in computing to prevent malicious invaders doing harm there too.

The brain’s intelligence is embodied in connections between fixed neurons, whereas the immune system’s is based on transient interactions between mobile immune cells. The principle is the same, however, and both can be replicated in a computer program.

For the past few years, Johannes Textor at Radboud University in the Netherlands and his colleagues have been building AIIs in the form of computer-based populations of simulated T-cells. Each simulated immune cell has unique properties and they collectively learn through reinforcement, with cells that make a positive contribution to eliminating simulated pathogens replicating, and those that don’t dying out.

Already, AII is helping immunologists make progress on some age-old problems. For example, Textor and his colleague Inge Wortel have built an AII to test a long-standing idea in immunology that explains how T-cells learn what is a threat.

Real-life T-cells have surface receptors that recognise proteins or fragments of proteins called peptides displayed on the surface of other cell types. These peptides are usually the breakdown products of old, malfunctioning proteins inside the cell, which are transported to the surface and displayed for T-cells to inspect. If the T-cells recognise the peptides as “self”, they allow the cell to go on its way. But if a cell is making non-self peptides, because it is infected with a virus or is cancerous, the T-cells attack.

One of the most important lessons the T-cell population has to learn is how to distinguish self from non-self in order to avoid launching autoimmune attacks. The textbook version of this is that young T-cells, called thymocytes, are dispatched to the thymus to face a loyalty test. After being presented with all possible self peptides, any of the cells that attack are eliminated.

There are problems with this, however.

GET TO KNOW YOUR IMMUNE SYSTEM

INNATE IMMUNE SYSTEM
This is the body’s first line of defence against pathogens. It responds rapidly to general threats and can distinguish between different classes of pathogen to recruit the most effective form of adaptive immune response to eliminate them.

ADAPTIVE IMMUNE SYSTEM
This system is activated in response to specific pathogens. It forms an immunological memory of threats we have faced, enhancing our future immune responses.

T-CELLS
Part of the adaptive immune system, T-cells attack invading pathogens and infected cells. They can act as “helper cells” by supporting B-cells to produce antibodies.

B-CELLS
These are involved in both the innate and adaptive immune system and are responsible for mediating the production of antibodies against specific pathogens.

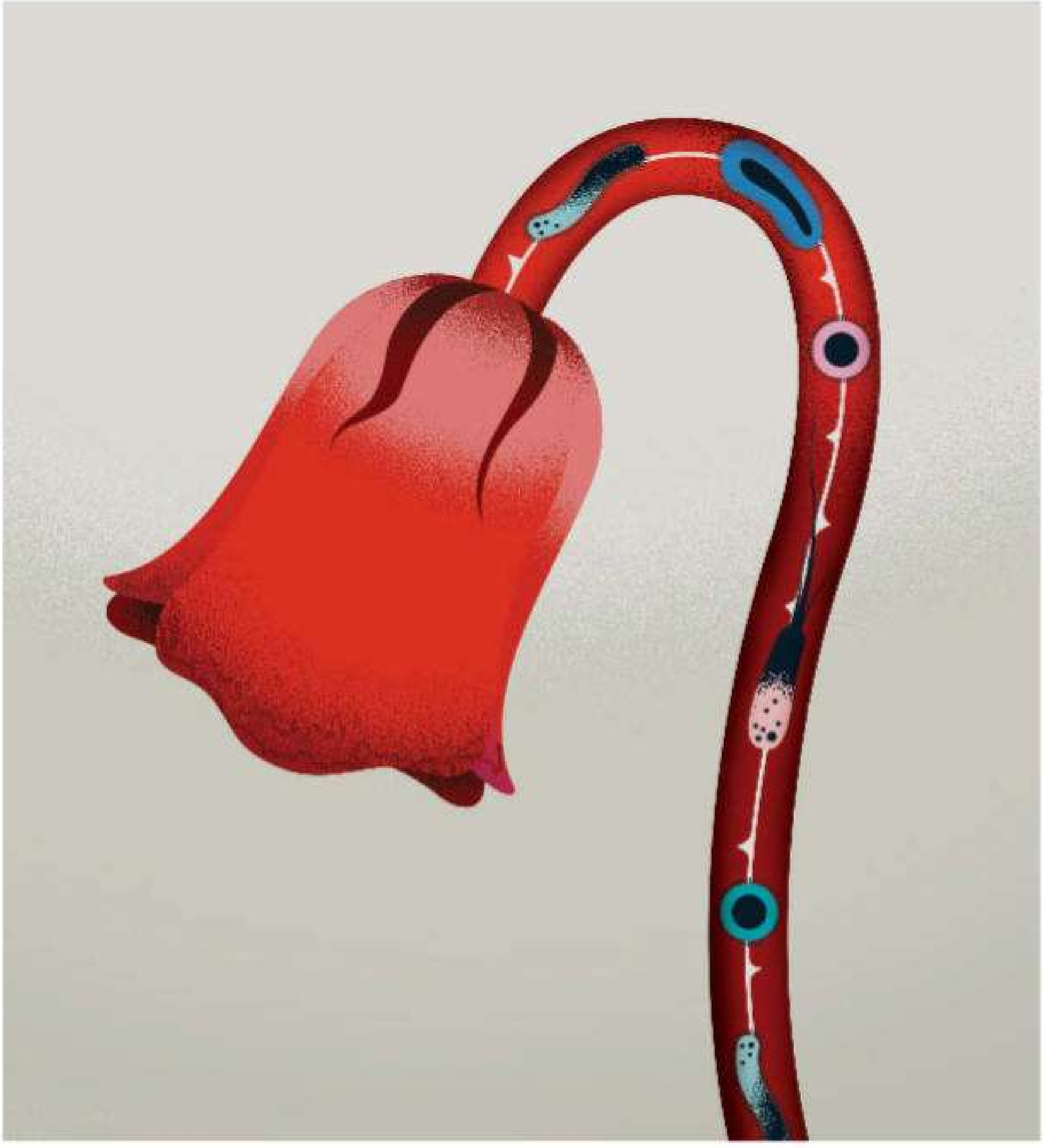
NATURAL KILLER CELLS
These innate immune system cells provide a rapid response to viruses and other pathogens. They can kill cells in the absence of antibodies.

NEUTROPHILS
These cells travel to a site of infection, where they destroy bacteria or viruses by ingesting them and releasing enzymes that kill them.

MONOCYTES
These large white blood cells travel to an injury or infection and turn into a macrophage or dendritic cell. Macrophages surround foreign material and ingest, kill or remove it. Dendritic cells boost immune response by presenting antigens on their surface to T-cells.

ANTIGEN
A molecule from foreign material such as a virus or pollen grain that binds to a specific antibody or T-cell.

ANTIBODY
These y-shaped proteins recognise specific antigens on foreign objects and bind to them. This tags the unwanted object for attack by the rest of the immune system. Antibodies can also neutralise foreign material directly.



The number of self peptides in a human is around a million, whereas estimates of how many a thymocyte could encounter during its two or three-day residency in the thymus are much lower. And it has become clear that masses of rogue T-cells get around the test.

One possible explanation is that this is all a learning process, where thymocytes encounter a subset of self peptides and the system generalises from these. So Textor built an AII of the process and showed that, under the right circumstances, T-cells can generalise from a subset of self peptides and later respond much more strongly to non-self peptides, such as from the Ebola virus, HIV and other pathogens.

Although in its infancy, the use of AIIs goes beyond improving our understanding of the immune system. Textor says he can see applications in a field called adversarial information, where part of a data set, such as search engine results, has been maliciously manipulated and needs to be weeded out. Traditional AI struggles with this, he says, but AII – which, after all, is based on a system that evolved to spot and eliminate intruders – could probably manage it.

Graham Lawton

HOW DOES YOUR IMMUNE SYSTEM CHANGE AS YOU AGE?

JUST as many parts of our body change as we get older, so does our immune system. But contrary to popular belief, emerging evidence suggests it isn't all downhill.

Let's start at the beginning. Because of their lack of previous encounters with pathogens, young children are vulnerable to all kinds of infections (see "What effect did lockdowns have on children's immune systems?", page 40). Newborn babies have some protection thanks to antibodies that cross the placenta to reach the fetus during pregnancy and linger in their bodies for weeks to months. Some antibodies are also passed on through breast milk.

Vaccines are recommended for babies in the order in which protection from these antibodies wanes. For instance, a vaccine against whooping cough is given at 8 weeks of age, because so-called maternal antibodies to this infection fall quickly.

Once babies and children start mixing with other children at nurseries and schools, there is a surge in respiratory illnesses, stomach bugs and other infections they haven't encountered before. We gradually encounter more and more pathogens, leading to immunity against them that can last a lifetime. Even infections that are too mild to notice can lead to immunity.

Fetal influence

In adulthood, pregnancy leads to temporary changes in the immune system, with some immune cells becoming less active to make sure the fetus isn't rejected. This can mean pregnancy leads to a higher risk of infections, such as flu and covid-19. However, early work suggests that part of the immune system, called natural killer (NK) cells, is bolstered during the later stages of pregnancy. In lab tests, NK cells from those who are pregnant are more active against cancer cells than NK cells from those who aren't.

As people get older, the immune system generally offers less protection. There is shrinkage of the thymus gland, an organ in the neck where T-cells are trained to attack pathogens. B-cells, which make antibodies, become less effective. And after menopause, lower levels of the hormone oestrogen may also contribute to weaker immune activity (see "Are there sex difference in the immune system?", page 42).

The immune system also wastes resources targeting a pathogen called cytomegalovirus (CMV). Most people have been infected by this virus without noticing, but it persists in tissues such as the salivary glands. As we age, an increasing proportion of T-cells are dedicated to attacking this virus. "CMV is constantly stimulating the immune response, but you can't get rid of it," says Paul Griffiths at University College London.

The general immune decline with ageing contributes to older people being worse hit by infections such as covid-19, flu and pneumonia. They respond less well to vaccines too. This decline can also result in the reactivation of viruses previously held in check, such as the chickenpox virus, leading to shingles. And it may contribute to the increasing incidence of cancer as people age.

But older people aren't always worse off. In 2009, a new strain of flu crossed from pigs to humans, which led to a swine flu pandemic. In contrast to most flu strains, people over 65 were less likely to become sick or die from swine flu than younger people, which was probably because they had some immunity from related flu strains that had circulated in their childhood. ▮

Clare Wilson

ANUP SHAH/GETTY IMAGES

Murderous mongooses

Banded mongooses may look cute, but they have a propensity for extreme violence that we are just getting to grips with, finds **Graham Lawton**

WHEN you first encounter a band of banded mongooses, your initial instinct is to think: "Aww! They are so adorable, so cute, so fluffy." My first encounter with them was in Queen Elizabeth National Park in western Uganda, which is beautiful and thick with wildlife.

I was under the expert eye of Robert Businge, one of the researchers on the Banded Mongoose Research Project based there. Businge located the group with a radio tracker and made a special call: pu-pu-pu-pu-pu. Out of the bushes tumbled seven bundles of chirruping, inquisitive enthusiasm. He checked they were all present and correct, recorded some data, then told me a horror story about beheadings.

The more I learned about banded mongooses, the more I understood just how deceptive appearances can be. They are aggressively violent animals that wage war on neighbouring groups, brutally murdering and maiming their rivals. They ruthlessly expel close relatives from their group and kill them if they won't leave, commit infanticide – sometimes against their own offspring – and even engage in cannibalism. "Their whole society is built around warmongering," says project leader Michael Cant at the University of Exeter, UK.

Such brutal, organised violence is unusual in the animal kingdom. I had come to the park to try to see it for myself, watching as the researchers put mongooses on a war footing with their enemies' faeces and a Bluetooth speaker, and took drone footage to reveal new details about this gruesome behaviour. These experiments are just the start. In the future, the team hopes these complex animals might give us some insights into our own tendency for violence.

The banded mongoose (*Mungos mungo*) is one of 25 species of mongoose in Africa. It is about the size of a domestic cat, though shaped more like a weasel, with a pointy nose and stripes. It is a predator, eating mainly millipedes and beetles, but also rodents, lizards and small snakes. While most species of mongoose are solitary, banded ones live in colonies, called bands, of between eight and 55 individuals, occupying a territory of about a square kilometre.

Their social structure is weird. "They do strange things," says Francis Mwanguhya, part of the Banded Mongoose Research Project. There is a subtle dominance hierarchy based on age that involves multiple dominant females, and there are two or three dominant males that jealously chaperone the females when they are in oestrus and do all the mating. The rest of the males are celibate subordinates.

Unusually, every female is allowed to breed. Uniquely, they all give birth on the same night, four times a year. "The pups get mixed up and don't know who their mother is," says Businge. The mechanism of this "supersynchrony" is

Banded mongooses live in colonies of between eight and 55 individuals and often start wars with rivals

unknown: the females, starting with the dominants, mate over the course of a week, with some giving birth prematurely to hit the deadline. If it goes wrong, and a pregnant female fails to deliver on time, every single one of the pups is killed and sometimes eaten. If this takes place in the open, the aftermath can look like a battlefield. "It's carnage, headless bodies, half-eaten bodies," says Cant. "The group is run by infanticidal females."

If they survive, the pups are suckled collectively and babysat by males in their dens. Once out of the den, at 4 weeks old, each pup gets a dedicated, unrelated escort – another unique feature of mongooses – that looks after them for a month and shows them how to forage – demonstrating, for example, which millipedes need cleaning before being eaten.

These peculiar social arrangements make banded mongooses a really useful model of the evolution of co-operative behaviour such as altruism, one of the great mysteries of biology. Cant and his team have been studying them in Queen Elizabeth National Park for 27 years, discovering birth synchrony and other unusual aspects of banded mongoose society.

The national park is on the shore of Lake Edward, close to the border with the Democratic Republic of the Congo and a cobra's spit from the equator. It is home to elephants, hippos, lions, leopards, buffalo, hyenas and warthogs, which form a special relationship with banded mongooses (see "Unlikely friends", page 46). There are also pythons, baboons, countless gorgeous birds – plus a spectacularly ugly one, the marabou stork. The Banded Mongoose Research Project is currently tracking about 10 mongoose groups of perhaps 250 individuals. Many are habituated to humans and will come to the researchers' call without fear.

"Their whole society is built around warmongering"

One reason for studying banded mongooses is their propensity for violence. If a group gets too big or too inbred, an eviction is in order. A handful of individuals are attacked and hounded out, or killed if they won't leave. The evictees wander the bush for a few weeks until they are eaten by eagles, leopards, lions or cobras – the leading cause of death among adults, which have a life expectancy of three to four years – or encounter a group with too many involuntarily celibate males, which voluntarily evict themselves to form a new group.

Eviction is relatively gentle for banded mongooses. They also wage war on their neighbours, invading their territory and fighting tooth and claw, sometimes to the death. The two groups face off in lines like in a medieval battle, issuing shrill war cries, then pile into one another. Males do the fighting and come off worse. If one gets separated from the melee, he is in big trouble. "They pin you down on your back, spread your legs and all bite you and you die from injuries," says Businge. Such deaths are quite rare: the adult mortality rate in battle is about 0.5 per cent, comparable with the historical average for human conflict. But serious injury is common.

Over the years, Cant and his team have observed 579 banded mongoose wars, which is a tiny fraction of the number that must have occurred. One of their studies found that banded mongoose groups can fight a war up to four times a month.

There are many reasons to declare war. Cant initially thought it was all about mating, with the dominant females leading the charge while in oestrus and using the chaos of battle to give their guards the slip so they can mate covertly with males from the other group. Around 20 per cent of banded mongoose pups are conceived this way, says Cant. This is a form of exploitative leadership where the leader gains benefits at the expense of her cannon fodder, but it could benefit the group by reducing the amount of inbreeding, says Cant.

Love or war

But covert mating isn't the only casus belli. When they looked more closely at their records, the researchers discovered that 417 of the 579 wars didn't involve females in oestrus. These appear to be more about status, territory, resources – and genocide. Many seem to be initiated by males and deliberately target the rival group's young. Around 20 per cent of all pup deaths of known cause occur in wars, with female pups twice as likely to be killed, which partly explains the typical sex ratio in a group of 1.6 males to every female. "It's a good idea to target female pups in a rival group, they are the lifeblood of the group and if you knock them out, the group is going to go extinct," says Cant. The winning group can then expand its territory to access more foraging areas.

According to Businge, a group can estimate the strength of its foe before the war starts, possibly by footprints or scent. If they have a numerical advantage, the mongooses will attack. If not, they retreat. Where groups are of similar strength, the war can escalate, with waves of attacks from both sides until one group backs down or a truce is called and peace breaks out – temporarily.

Exactly what goes on in a fight is hard to fathom. It is total mayhem, with the males from both sides forming a screaming, roiling maul. "They kick up a dust storm and it's deafening" says Cant. There are pincer movements and flanking charges. It is sometimes possible to see females sneaking off to make love not war, but the actual fighting is a ball of confusion. How groups coordinate their movements and what determines success or failure remain unknown.

After 10 to 20 minutes – though battles between large, well-matched groups can rage for an hour or more – one side backs down and scarpers, leaving its walking wounded limping in its wake.

Cant recounts these stories of love and violence over an evening beer or three. The following morning, I am hoping to see it in action as we are preparing for war. The team is planning an experiment to induce battle behaviour in a 35-strong group of unhabituated banded mongooses, using faeces from another group – which smells horrible, according to Businge, and I take his word for it – and an audio recording of their battle cries on a Bluetooth speaker. Cant is going to film the unfolding drama with a drone.

We locate the group and let them acclimatise to our presence. The mongooses approach warily, but are soon happily rootling around looking for insects, squeaking and chirruping. (The calls encode two bits of information: who they are and what they are doing, "Joe digging", "Sue searching", "Kit moving".) They are clearly interested in the faeces, sniffing around it and scent-marking the slab it is presented on. Then the drone goes up – it is noisy but doesn't spook the mongooses – and the action begins.

When Mwanguhya plays the war cry, the reaction is instant: the scattered mongooses

Unlikely friends

Another unique feature of banded mongooses is that they have a mutualistic relationship with another mammal – the only known mammal-mammal mutualism in the world. Their partner is the warthog, a very common sight in Queen Elizabeth National Park in Uganda.

Mutualisms usually involve species from different groups, such as bees pollinating flowers, oxpeckers pecking ticks off buffalo and birds cleaning crocodiles' teeth.

The warthogs appear to initiate the process, approaching the banded mongooses and flopping down. The mongooses then go to work cleaning the hogs – presumably of parasites, though nobody knows for sure – and get an easy meal in the process. The interactions last a few minutes and can involve several mongooses, until the warthog has had enough and shrugs them off.

The mutualism is somewhat artificial. Banded mongooses and warthogs rarely interact in the wild, but come together at the rubbish dump in Mweya, a village in the park.

"The mongooses must be picking something off," says Leela Channer at the University of Exeter, UK, who has just started the world's first study of this interaction. "Ticks or lice, or maybe cleaning off the mud." Let's just hope they stay friends and don't start a war.

Banded mongooses like to clean warthogs, presumably for a snack in return

MARK MACEWEN/NATURE PICTURE LIBRARY/ALAMY

DANITA DELIMONT/ALAMY

LEELA CHANNER

Banded mongooses (left) are being studied at the Queen Elizabeth National Park (above) in western Uganda

coalesce as a group, writhe around in a ball and then suddenly flee as a phalanx. This time, they decided to retreat, possibly because they are at the edge of their territory, says Businge. But, on other occasions, they have confronted the "enemy" in battle formation.

Surprise attack

The drone footage is revealing that the mongooses mass around a single individual for a few seconds, which then apparently makes the call to retreat and leads the group off. It isn't known whether that mongoose is a male or female, or a recognised war leader, or how it communicates to the group.

The next day, we try again with a larger group that Cant thinks will be more belligerent. We use the same set-up and, sure enough, the mongooses line up in battle formation and start a cacophonous advance on the bush where the speaker is hidden. They keep inching forwards and then sidle into the bush as if to launch a surprise flanking attack. If there were real rival mongooses in there, I daresay they would have had their furry butts kicked.

The drone footage of this experiment is a world first, and a dry run for Cant's next project. The plan is to use GPS collars to track all of the banded mongooses in real time (the researchers currently attach radio collars to two members of each group), keep a weather eye for warnings of an impending war and then launch a drone to film it. The team will then use AI to analyse the footage to understand which individuals started the fight, which coordinated each side and what determined success and failure. "This new technology gives us a completely new perspective," says Cant.

The hope is that one day we will be able to learn something about the evolution of our own bellicose tendencies. According to Cant, warfare is one of the key forces shaping the evolution of cooperation and social behaviour in humans, as well as our tendency to dehumanise outsiders. "Humans and mongooses are among the most warlike animals on the planet," he says.

> **"We may not need language and higher cognition to engage in warfare"**

The idea of studying warfare in banded mongooses and applying it to humans is in its infancy. "Using animal models to better understand human warfare, I think, is a very interesting and promising new perspective," says social psychologist Carsten de Dreu at Leiden University in the Netherlands. "For a long time we thought human warfare was something cultural and specific to our species." As well as banded mongooses, other animals that live in groups, including lions and chimpanzees, can display similar behaviours to the way humans go about warfare. "The beauty of using animal models is that we can see the basics, we may not need language and higher cognition to engage in the type of warfare humans engage in," he says.

Uganda has endured plenty of human conflict – colonialism, the reign and overthrow of military dictator Idi Amin, the civil wars of the 1980s and 90s and the recent reign of terror by the Lord's Resistance Army. On my last day in Mweya, the village in the national park where I was staying, I met two 20-something brothers who lost their parents in that insurgency. I thought of my own sons. I thought of Ukraine and the threat hanging over all of us from nuclear weapons. I thought about coming conflicts over climate change.

Is it possible that banded mongooses will give us insights into our own tendencies? "The evolution of culture and intelligence obviously make humans potentially very different to other species, and that must always be kept in mind," says Kevin Foster at the University of Oxford, who studies war in bacteria. "For this reason, I am not yet confident that the study of animal or bacterial warfare will teach us a great deal about human warfare specifically, but I think it deserves exploring."

Meanwhile, the banded mongooses have a new conflict brewing: with marabou storks. They meet on the rubbish dump in Mweya, an unnatural situation created by humans. The storks are scavengers and have learned that they can scoop up banded mongoose pups and swallow them whole. The mongooses have yet to learn that the storks are a threat. "I don't study mongooses for their cognitive abilities," says Cant. Some species, it seems, never learn from experience. ■

Graham Lawton is a features writer at *New Scientist*

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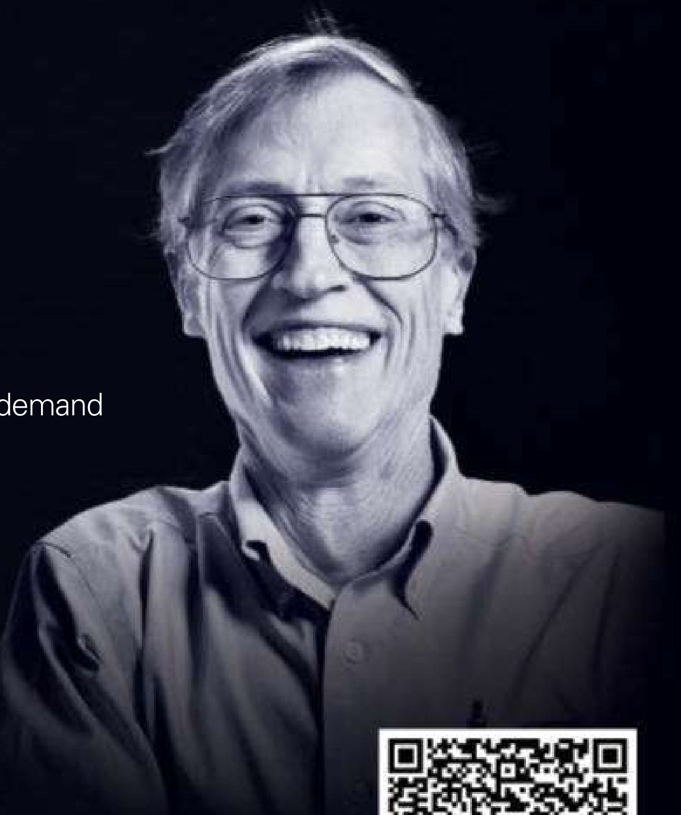

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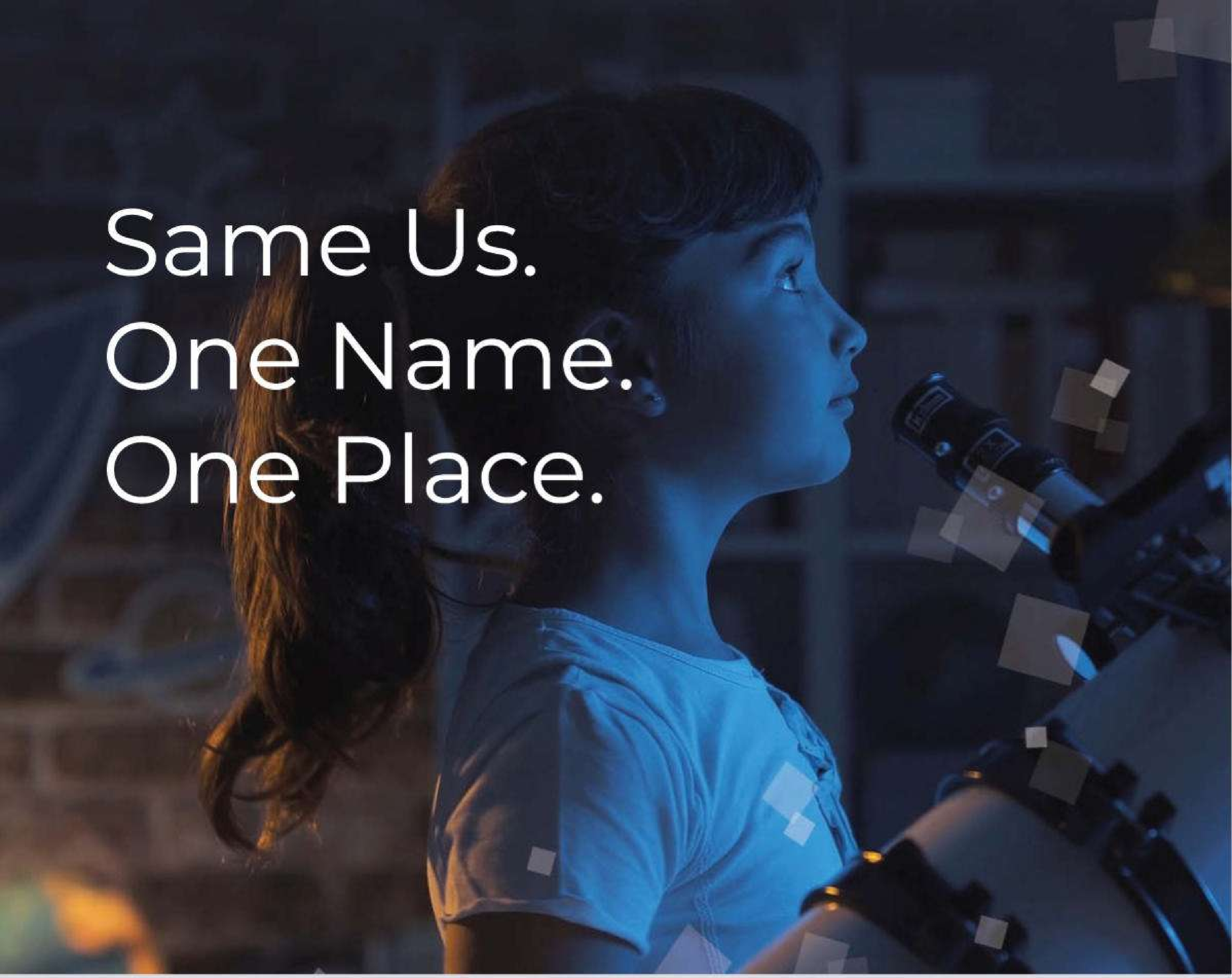
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Stargazing at home

Shooting for the moon

The moon's brightness might frustrate some stargazers, but a closer look will reveal some amazing features, says **Abigail Beall**

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

What you need

Binoculars or a small telescope
Clear skies

Stargazing at home appears every four weeks. Share your stargazing successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistStargazing

Next week

Science of gardening

THE moon annoys some stargazers. This is especially true when it is full and its light outshines some stars usually visible to the naked eye or prevents meteor showers from giving their best show. But I would like to invite you to embrace the part of the lunar cycle when the moon is at its brightest, which, this month, falls on 5 February. Join me in casting an eye towards our beautiful companion.

The best time to look at the lunar surface isn't right at the full moon, because the sunlight reflecting off its face can be too bright to see all of its details. You will get a better view a few nights either side, when most of the surface is still visible, but the light isn't quite so intense.

MATT CARDY/GETTY IMAGES

If you have ever done more than just glance at the moon, you will know it has some fuzzy patches of light and dark. With binoculars or a small telescope, these patches spring into astonishing detail.

The first features we are going to focus on are the lunar maria, which is Latin for seas. They were given this name because early astronomers thought they might be just that – vast areas of water. Although we now know the moon does have some water on its surface, it is probably just in ice form or in individual water molecules within grains of rock.

Instead, these dark areas, which can be seen dotted across the moon's surface, are stretches of basalt rock formed by volcanoes around 3 billion years ago. They are dark simply because this kind of rock reflects less sunlight.

Next, we will look for some impact craters. The biggest of these are Copernicus, which is a bright, 93-kilometre-wide crater that is roughly in the middle of the moon, as we view it, and Tycho, which appears at the bottom of the moon as seen from the northern hemisphere, and at the top from the southern hemisphere. If you look outwards from the centre of Tycho, you might see some bright streaks. These were caused by material thrown out from the spot of the impact when the crater was created around 108 million years ago.

On the other side of the moon's face from Tycho, in between two of the biggest lunar maria, there is a curved line that appears slightly brighter than its surroundings. Look closely and you might spot some ridges. This is Montes Apenninus, one of the biggest mountain ranges on the moon. It was created by asteroid impacts about 3.9 billion years ago. In general, the bright patches on the moon's surface are its highlands, which were mostly put there when something big smashed into it.

If you want a challenge, at very specific times in the lunar cycle, two features become visible thanks to the way sunlight falls on the edges of craters. The lunar X and V look like these letters dotted on the moon's surface, and can be seen for about 4 hours around the first quarter of the cycle. ▮

These articles are posted each week at newscientist.com/maker

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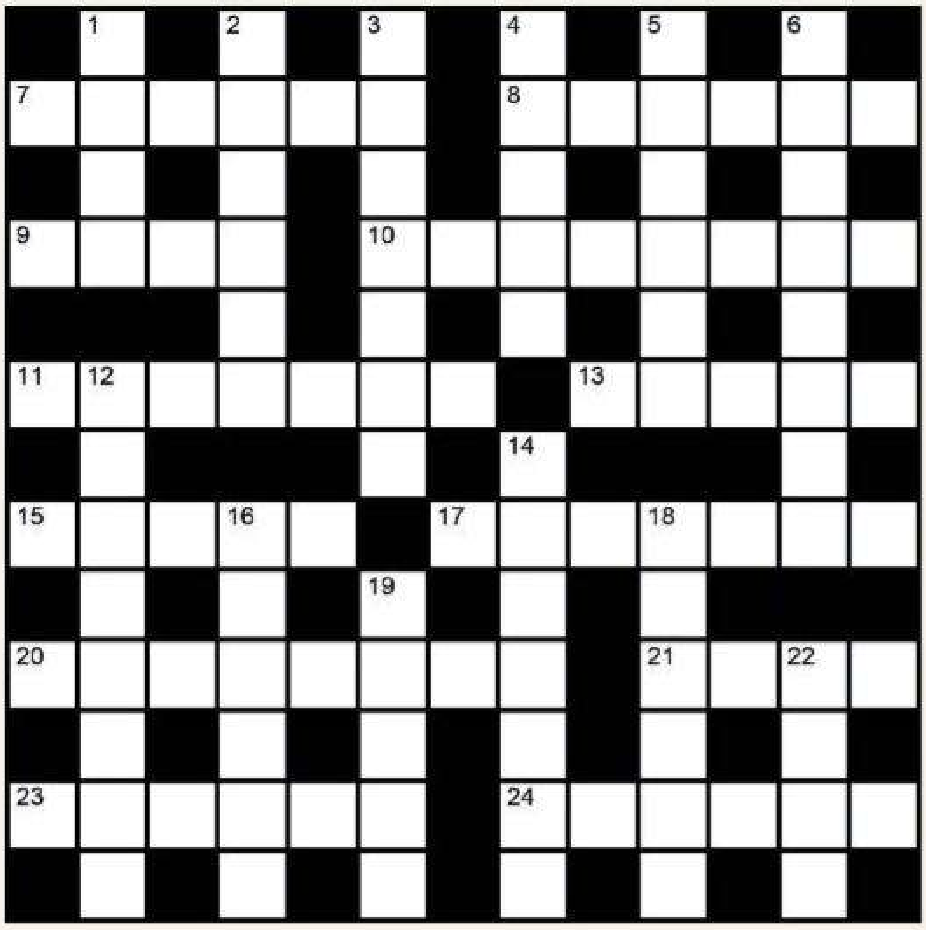
Cryptic crossword #102 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

7 Divulge answer within party (6)
8 Cat starts to chow on regurgitated meat sauce (6)
9 PR agent understood criticism (4)
10 Thomas dissected around 2000 large animals (8)
11 Bird of prey is more frightening when rook takes one's place (7)
13 Pass time in New York after eating on vacation (5)
15 Bright star distracts Picard, to some extent (5)
17 Wind from Asian country, mostly oxygen – agreed? (7)
20 Kelvin having a rest, making tools (8)
21 I pursue the best antelope (4)
23 Sci-fi author gets behind sixth space mission (6)
24 Woodlouse perhaps flipped in judo position (6)

DOWN

1 Man who invented ringer (4)
2 Anorak extremely into ale glass (6)
3 Climb, carrying licorice roots over hardened resin (7)
4 Mischievous child finds sulphur at temporary accommodation (5)
5 Gundog terrorised large, slow creature (6)
6 Aggressive behaviour shown by leaders of space module, only just below speed of sound (8)
12 Body part that appears at the end of textbooks? (8)
14 Penicillin pioneer embraced King George, causing irritation (7)
16 Detectives surround up-and-coming health centre to find shell (6)
18 Idea: make meal of onion – about time! (6)
19 Calls planet's features (5)
22 Pressure on line at front (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #187

set by Bethan Ackerley

1 Which of these isn't a type of white blood cell: a basophil, a monocyte or a megaloblast?

2 What name is given to the positive terminal of a battery?

3 What does the Enhanced Fujita scale measure?

4 Nobel prizewinner Konstantin Novoselov is best known for his work on which material?

5 Small, dark clouds of cold gas and dust in interstellar space are known as what?

Answers on page 55

Puzzle

set by Zoe Griffiths

#207 Total recall

I recently had the incredible opportunity of talking to an intergalactic traveller about her encounter with four extraterrestrial beings.

"The aliens have purple skin, long, floppy legs and large orange eyes," she told me. "And they revealed to me the true nature of dark matter."

I leaned in close with excitement.

"Unfortunately, I don't remember anything about that. I do remember a great puzzle they told me, though. I asked them their ages, and they said that if you sum up the ages of only three of them, the possible totals are 24, 53, 54 and 61. From this, they told me that I could work out all four of their ages."

Well, it isn't exactly the secrets of the universe, but it will have to do. Can you work out the ages of the four aliens?

Solution next week

Differently sweaty

Is sweat from a different cause – such as exercise, anxiety or illness – chemically unique? Can dogs tell the difference?

Claire Guest
Medical Detection Dogs, Milton Keynes, UK
In short, yes. Sweat is mostly composed of water, but it also plays a role in the excretion of toxins and waste products from the body.

These substances can be hormones, minerals or volatile organic compounds (VOCs) produced as a by-product of disease. They can vary from person to person and depend on the cause of perspiration.

For dogs, which possess up to 300 million olfactory receptors, sniffing out the difference can be easy once they are trained to detect a specific scent. For instance, in a 2022 study by researchers at Queen’s University, Belfast, and Newcastle University, both in the UK, dogs were trained to detect compounds associated with stress in breath and sweat samples taken from participants before and after completing a stressful mental arithmetic task. This suggests that we produce different odours when we are stressed than we do when relaxed.

> **“In my experience, the smell of sweat from vigorous exercise is quite different from that of sweat from a different cause”**

For those of us at Medical Detection Dogs, these findings came as no surprise. In our 15 years of training dogs to detect disease, we have used skin swabs or sweat samples in projects such as the detection of Parkinson’s disease, malaria and covid-19, even when asymptomatic.

The dogs can pick up on subtle changes and detect both hyper- and hypoglycaemic episodes for people with type 1 diabetes.

We also use sweat samples to train medical alert assistance dogs for clients with health conditions such as postural orthostatic tachycardia syndrome and Addison’s disease.

Interestingly, while disease-specific VOC patterns have been identified for some conditions, the exact odour molecules that dogs use to detect them aren’t yet known.

However, further research that combines canine olfaction with chemical profiling could help further our understanding of how dogs differentiate between the chemical “fingerprints” left by changes in hormone production or our microbiome, and also help improve the early detection of disease.

Joy Milne, super-smeller
Perth, UK
I am fortunate (or unfortunate, depending on how you look at it) to have a very sensitive sense of smell.

In my experience, the smell of sweat resulting from vigorous exercise is quite different from that of sweat from a different cause, especially if someone is ill. I think the variation is due to different volatile chemicals in the sweat.

For me, the sweat from exercise where you get really out of breath has a distinctive salty smell to it. I can also tell the difference between people of different sexes and age groups. Sweat from men and women, older and younger people, each has a distinct smell.

I don’t have much experience of the smell of sweat from anxiety, so I couldn’t comment on whether this has a distinct odour.

When I was a nurse, patients were often anxious, but that was usually linked to an illness they had, such as heart disease or diabetes. It wasn’t pure anxiety alone.

The sweat of people with a very high temperature has a distinct chemical smell, due to their infection. When the person is getting better, the smell reduces.

To me, covid-19 and flu have distinct smells, and there are also differences depending on whether someone has a viral or bacterial infection. Everything produces different volatiles.

[To read about how Joy Milne’s incredible sense of smell is being used to develop a new diagnostic test for Parkinson’s disease, go to newscientist.com/article/mg24132200-300-meet-the-super-smeller-who-can-diagnose-parkinsons-at-a-sniff/]

MARCO BOTTIGELLI/GETTY IMAGES

Is there any difference between a sunrise and sunset, in terms of the light quality alone?

This week’s new questions

Sundowner **Is it possible to distinguish sunrise from sunset from an image (i.e. with no knowledge of the direction in the sky or time of day, and in a time frame with no discernible solar motion)?** ***Jeremy Smith**, Plymouth, Devon, UK*

Stirring it up **What is the most efficient way to stir to dissolve something in water: with circular motions, chaotic ones, fast or slow?** ***Scott Haslam**, Manchester, UK*

Heavy handed

Why do speakers at public events wave their hands around so much?

Chris Daniel
Glan Conwy, Conwy, UK
It is said that the majority of our communication is non-verbal.

When a person is talking to a large group of people, whether in a lecture theatre, open-air event or on stage, the distance between the speaker and the audience means that gestures have to be proportionally bigger to convey meaning and emotion.

I find I do this when teaching. Wide, expressive arm movements, exaggerated body posture and pacing around the room that would be totally inappropriate in normal social gatherings feel quite suitable in front of a class of students – at least, nobody has told me otherwise.

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Tom Gauld
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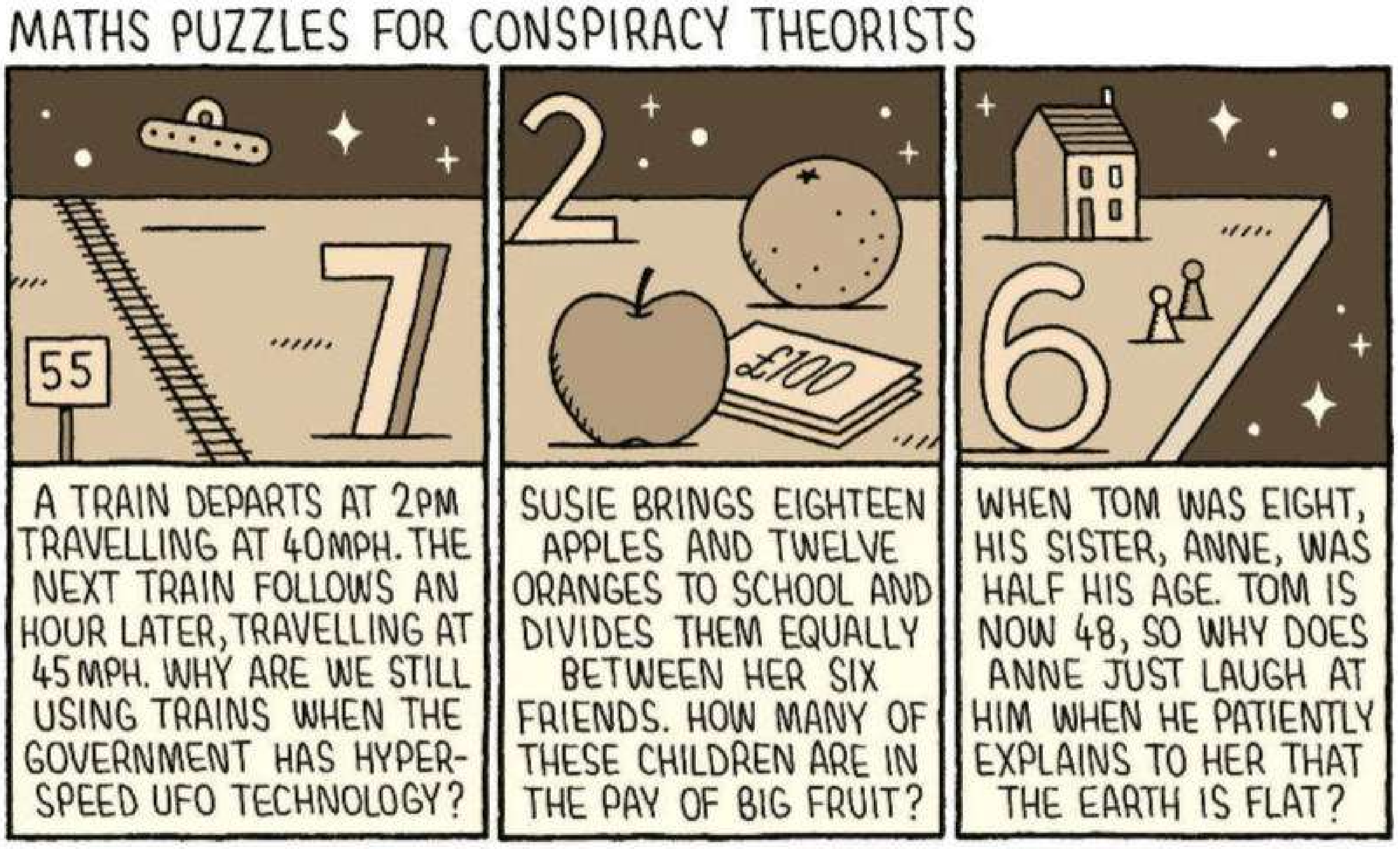

MATHS PUZZLES FOR CONSPIRACY THEORISTS
7
55
A TRAIN DEPARTS AT 2PM TRAVELLING AT 40MPH. THE NEXT TRAIN FOLLOWS AN HOUR LATER, TRAVELLING AT 45 MPH. WHY ARE WE STILL USING TRAINS WHEN THE GOVERNMENT HAS HYPER-SPEED UFO TECHNOLOGY?
2
£100
SUSIE BRINGS EIGHTEEN APPLES AND TWELVE ORANGES TO SCHOOL AND DIVIDES THEM EQUALLY BETWEEN HER SIX FRIENDS. HOW MANY OF THESE CHILDREN ARE IN THE PAY OF BIG FRUIT?
6
WHEN TOM WAS EIGHT, HIS SISTER, ANNE, WAS HALF HIS AGE. TOM IS NOW 48, SO WHY DOES ANNE JUST LAUGH AT HIM WHEN HE PATIENTLY EXPLAINS TO HER THAT THE EARTH IS FLAT?

***@Hascombes**, via Twitter*
For some people, hand gestures add emphasis or imply importance at certain points of their speech. For others, it can be due to nerves or a sense that they need to do something with their hands. The two reasons are often indistinguishable.

***@zubairedhy**, via Twitter*
Singers also do the same. The motor parts of the brain used for vocalisations and other movements, particularly hands, are intertwined.

***@AlexanderV878**, via Twitter*
It is supposed to be for the audience, but really it keeps the speaker focused on the topic and on their vocal performance.

***@Earthian_19**, via Twitter*
Personally, gesturing during a speech makes me comfortable on a stage. My thoughts flow freely and articulation becomes organic.

> **“Arm movements that would be inappropriate in normal social gatherings feel suitable in front of a class”**

***@theothersrk**, via Twitter*
To emphasise their points to help keep the audience engaged. By using hand gestures, the speaker can draw attention to their words and help create an emotional connection with the audience.

***@denkemarchen**, via Twitter*
Sometimes, the use of gestures is the result of training for effect. Other times, it is a personality thing. Personally, I can’t talk without waving my hands and arms around in an animated way, especially when it is an emotional or important issue to me.

***Day Hayes**, via Facebook*
Hand gestures are a helpful and necessary part of communication, but we aren’t as conscious of using them as we are with words or facial gestures. However, if you pay attention to them, you can use them to add to the impression you wish to make, such as openness or friendliness.

The reason public speakers consciously use hand gestures is to appear more human. There is nothing worse than looking at someone talking at a podium while they are stiff as a board like a rabbit in the headlights.

***@RottenHeadRed**, via Twitter*
Humans communicate and learn both orally and visually, so it stands to reason that the orator and the observer will be more engaged in the conversation when the visuals emphasise and complement the spoken word. They appear passionate and invested in the “story”.

Peter Meehan
London, UK
Speakers at public events may wave their hands to ventilate any hot air.

Robert Hickman,
Sudbury, Ontario, Canada
To keep their audience awake!

Answers

Quick quiz #187 *Answers*

1 A megaloblast
2 The cathode
3 The intensity of tornadoes
4 Graphene
5 Bok globules

Quick crossword #125 *Answers*

ACROSS 1 Equimolecular, **10** Adapt, **12** Autonomic, **13** Notum, **14** Cambium, **16** Inducer, **18** Pharynx, **20** Avatars, **22** SWORD, **24** Le Creuset, **26** On average, **27** Radio, **28** Solvay process

DOWN 2/11 Across Quantum computers, **3** Intensity, **4** Occam, **5** *Ex Machina*, **6** U-turn, **7** Aseptic, **8** Balance piston, **9** Isomerisation, **15** Maxillary, **17** Diametric, **19** Avocado, **21** Apsides, **23** DG ENV, **25** Clear

#206 All square *Solution*

Lagrangia (L) scored 576 in their first innings; the Pythagoreans (P) managed 225. In their second innings, Lagrangia scored 49 and the Pythagoreans reached 400.

We need four square numbers such that L1 + L2 = P1 + P2. We know that L1 > 300. We also know L2 < 50 and L1 + L2 is a square number. So, we need two square numbers over 300 that differ by less than 50. Adjacent squares are separated by larger and larger odd numbers, and the first two over 300 are 37 apart. This means that 37 < L2 < 50. The only odd square in this range is 49. If L2 = 49, then L1 = 576 and P1 + P2 = 625. We also know P1 < 376 and P2 > 249. The only square numbers that fit these criteria are 225 and 400.

On the origin of carrots

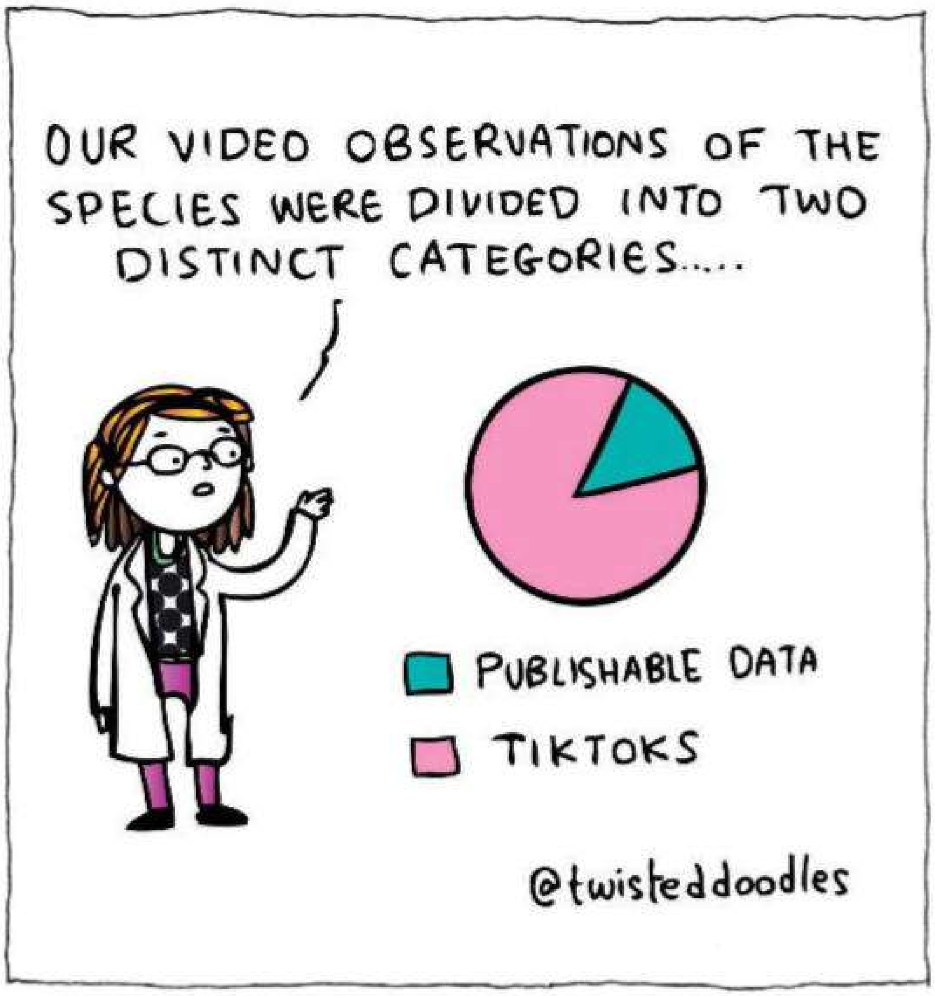
Do you know where your carrot, if you have a carrot, comes from? A new study from the University of L'Aquila in Italy outlines one approach to finding out.

"It must be noted..." the paper explains, "that the methods proposed so far for tracing the geographical origin of carrots as well as for discriminating between organic and conventionally grown carrots, are somewhat scarce." In this report, partially titled "Geographical discrimination of Italian carrot (*Daucus carota L.*) varieties", Samantha Reale and her colleagues explain exactly why and how they addressed that scarcity.

In a way, they accomplish some of what rabbits do: sniff out the origin of a number of long, pointy vegetables. But the researchers do so in a more high-tech manner. They propose a multi-part carrot detection method or, in other words, an "attenuated total reflectance Fourier-transform infrared spectroscopy... and headspace solid-phase microextraction followed by gas chromatography with mass spectrometry detection".

Experimenting on three varieties of Italian carrots, they say they were able to correctly identify, about 80 per cent of the time, which of three regions a carrot came from.

Twisteddoodles *for New Scientist*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Sticking points

A humble stick can yield up many insights. Of which here are three.

"The phenomenon of the 'howling wind'... occurs as strong winds whip around bare tree branches and electrical transmission lines," write Lutz Kasper and Patrik Vogt in a recent issue of *The Physics Teacher*. The two aimed to "create this sound in the lab by swinging sticks quickly through the air". They succeeded in this, and also in understanding how to shape the howl, finding that "the frequencies present depend upon the swinging speed and the diameter of the rod".

Pieter Jolly examines a more refined stick-based activity in his study "Dancing with two sticks: Investigating the origin of a southern African rite". His analysis, in *The South African Archaeological Bulletin*, centres on photos from 1910 or 1911. Jolly explains: "A particular posture adopted by dancers in some of these photographs, stooped and supported by two sticks, is represented in San rock paintings... This article investigates the symbolism of the dancing sticks and whether the rites in which these sticks are employed originated with the San or whether they originated with southern Bantu-speakers." Probably the San, he concludes.

Jinhua ham is one the world's great hams, with 800 years or so of history in China. Yet it stinks, sometimes. Despite being salted and dried, the meat can spoil, its stench trapped inside. Changyu Zhou and their colleagues are using sticks to investigate how Jinhua hams go bad. The researchers obtain their samples using the "three sticks" sniffing method: "Bamboo sticks are inserted into the sacral vertebra, knee joint and hip joint of hams, and then the aroma adsorbed on the bamboo sticks is evaluated by [a] professional panel."

Howling and Howling

Annoying as noise can be, moaning and groaning don't help to alleviate the problem. Howling does. So does Howling. Alan Howling and D.H. Howling. Christopher Howls, meanwhile, has an eye on acoustical catastrophes.

Alan Howling at the Swiss Plasma Center tinkers with new technology to perform a fairly conventional acoustic service: active noise cancellation. Howling and his team play with plasma electroacoustic actuators as an improvement over speakers that use a diaphragm in a rigid frame. A plasma actuator has no fragile moving parts. It does have some kinks, however, which Howling and his team are quietly attacking.

D.H. Howling at the Edison Laboratory in New Jersey wrote a paper called "Noise in magnetic recording tapes". This was in 1956, when magnetic tape was used for recording and playing back sounds. Howling tried to nail down what was causing unwanted noise in the recordings. He fussed mainly about subtle problems in the materials used to make the tape. The more obvious causes of noise, he wrote, had already been tamed "to a tolerable level": wow and flutter (fluctuations in the tape movement), friction and electromagnetic discombobulations ("chatter") between parts of the system.

But don't mistake Howlings for Howls. Christopher Howls at the University of Southampton, UK, has a paper coming out in which he and two colleagues cheerily worry about logarithmic catastrophes at acoustic event horizons, which are effectively sonic black holes.

The persistence of time

Peter Shaw tells of, and then shows, the strangeness of time. He wrote to Feedback at the end of January 2023: "Can any *New Scientist* readers beat this for a delay between writing and acceptance of a paper? Ours has just been accepted – in *Austral Ecology* – after 11 years and 15 journals! It shows that some small new world monkeys will risk bad stings for a new unit of energy, the Snickers bar. (To be pedantic, about half a Snickers bar). I bet someone somewhere will laugh and say 'Only 11 years – peanuts'."

Feedback wrote back to thank him. In return came this message: "I am now retired, though still interested to hear from you... – Peter Shaw January 2021". ▮

Marc Abrahams

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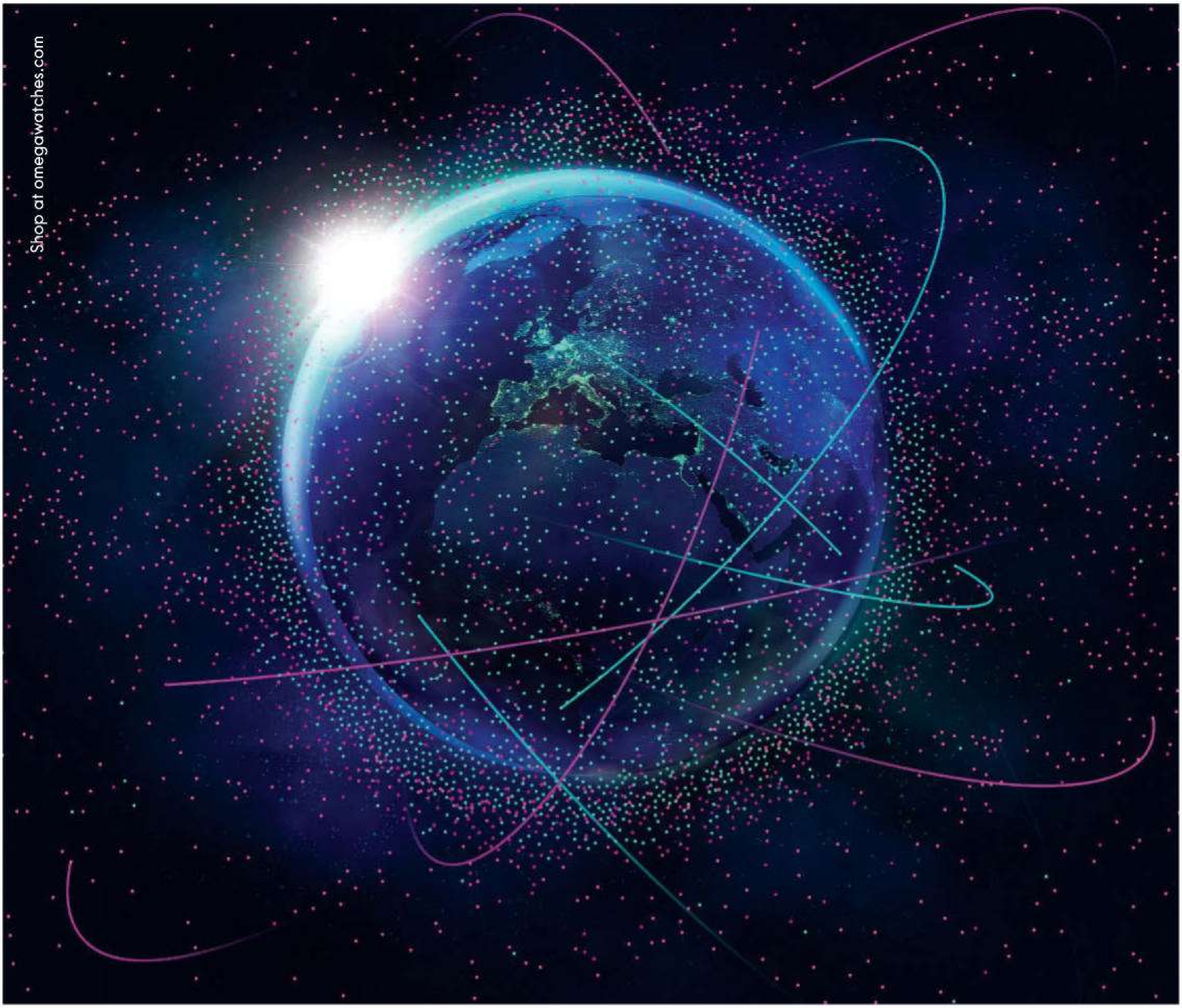

A MAP TO THE FUTURE

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